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EOS

Earth & Space Science News

Mars 2020 Mission

Earth Science Jobs: Seven Projections

Landsat Archive of Greenland Glaciers

SATELLITE DATA for Weather Forecasting

AGU
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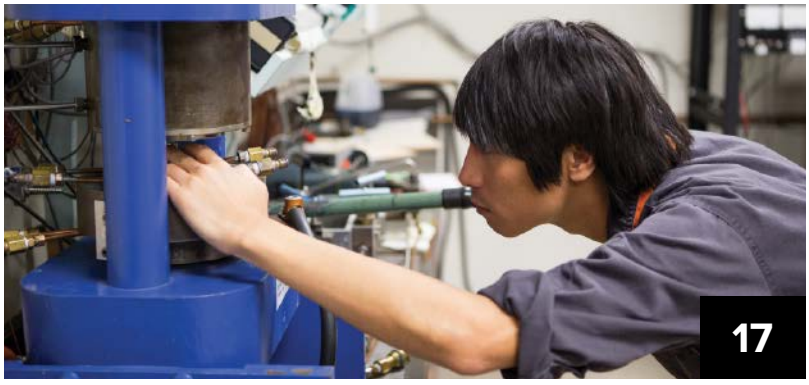

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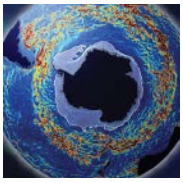

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Many satellite data streams combine to form a visual representation of weather patterns. Credit: NASA SPoRT (S-NPP/SSEC UW).

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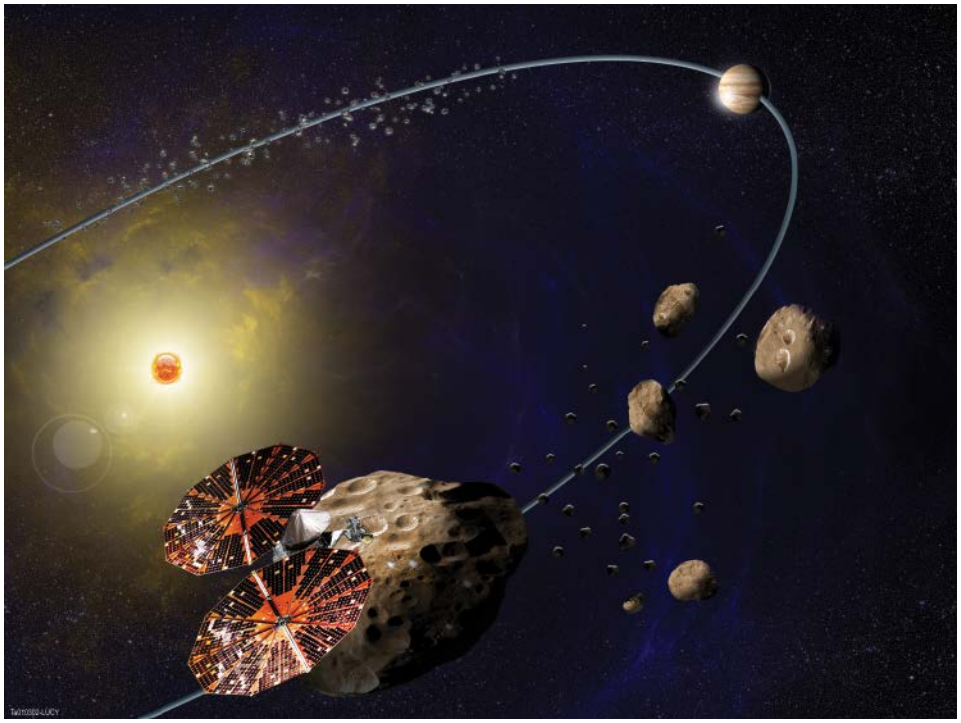
Upcoming Discovery Missions Will Look Back to Our Origins



Southwest Research Institute

Artist's conception of the Lucy spacecraft on its trajectory past several Trojan asteroids. Lucy is one of two proposed Discovery missions selected on 4 January to move ahead, after coming out on top in an intense competition.

NASA plans to kick off the 2020s with a return to our roots.

On 4 January, the space agency selected two Discovery missions to explore the earliest stages of our solar system. One mission, dubbed Lucy, will launch in October 2021 on a journey to the Trojans, an asteroid swarm that leads and trails Jupiter as it swings through its orbit. The other mission, called Psyche, will launch in 2023 toward the only metal asteroid in our solar system, potentially the frozen core of a long-dead planet.

Fierce Competition

These two missions (see http://go.nasa.gov/2jTPsSH) came out on top in a competition that started 3 years ago with a field of 28 proposed Discovery missions. Teams of scientists spent months preparing proposals for NASA to consider. The winners, chosen in a peer-review process, get funding, mission management, and systems engineering support from NASA.

NASA Planetary Science Division director Jim Green said that the process is extremely rigorous, putting proposals through "the toughest scrutiny you can possibly imagine. These teams are really put through the wringer."

"It was like a cross between the thesis defense from hell and some sort of Hollywood superproduction," commented Lindy Elkins-Tanton, principal investigator for the Psyche mission and director of the School of Earth and Space Exploration at Arizona State University in Tempe. The proposals are evaluated by a team of science, industry, and technical experts for the rigor of their science and their grounding in the National Academy of Sciences' decadal questions, the academy's list of broad issues to explore in planetary science over the next decade.

The panel evaluated the initial 28 proposals and selected five for the second round, which examined each proposal's implementation plan. Two proposals came out on top. "That whole process separates doing good science from doing the top science," Green said, "from going after the top questions that really move our field ahead." Lucy and Psyche were the best prepared to move ahead, he said.

Lucy in the Sky

The Lucy mission is named after the fossil that revolutionized our understanding of human origins. The mission team hopes to do the same for the origins of our solar system by exploring the Trojan population of asteroids, remnants from the solar system's formation.

Hal Levison, principal investigator for the Lucy mission and a planetary scientist at the Southwest Research Institute in Boulder, Colo., likened this goal to deciphering a crime scene. "Sometimes the blood splatter on the walls tells you more about what happened than the bodies on the floor," he said, "and in this case the splatters on the wall are the [asteroid] populations."

We know little about the Trojans, Levison said, but we do know that they exhibit great diversity. This variation likely stems from a wide range of origins: The asteroids developed in different parts of the solar system, then migrated to their present positions. "By studying those differences," Levison continued, "we're going to try to untangle how the planets moved around."

"Basically, the planets are aligning for us to do this mission," Levison said. Lucy's trajectory will carry it past six Trojan asteroids, including the Patroclus-Menoetius binary, a pair of asteroids whose high-inclination orbit prevents them from being studied easily. "It just so happens to be traveling through the plane of the solar system at the time the spacecraft is going by," said Levison, referring to the asteroid pair. "We have this unique list of targets that would be very hard to reproduce in the future."

Psyche: A New World of Metal

The Psyche mission will look at a feature that is the only one of its kind in our solar system: an asteroid made completely of metal. "This is not just a unique object," Elkins-Tanton said of the Psyche asteroid; "it's not just the only object like it in the solar system, but it's also an improbable object."

Psyche is most likely the core of a planet that formed early in the solar system but was so pounded by other objects that it lost its outer layers. This sort of occurrence could happen once or twice in a solar system but often doesn't happen at all, Elkins-Tanton explained. If it is a core, it will give insight into the early solar system as well as the cores of our own planets.

Elkins-Tanton said that the first job of the mission is to determine whether Psyche is, in fact, a naked core. "If it's not a core, then

it's something so exotic that it actually hasn't even been thoroughly hypothesized about," she remarked, "and that would be even more exciting."

In the course of the mission, the spacecraft will examine Psyche's magnetic field, composition, and surface topography. Elkins-Tanton is most interested in that final point. We don't know what metal craters look like, she said. On impact, molten metal could freeze into tall spires before it has the chance to fall back to the ground, or the surface could shatter like glass. It will be an unexplored metal world. "Everything we measure will be new," she said.

Peter Rubin (Arizona State University)

Artist's conception of Psyche's surface. Scientists are familiar with craters in rock and ice; the Psyche mission will reveal crater dynamics for metal surfaces.

A Snapshot of Our Beginnings

Both missions will trace the earliest stages of our solar system's formation. "It just so happens the two [missions] we picked go after completely different regimes in our solar system, but in the first 10 million years," said Green. Lucy will give us insight into the formation of the outer part of the solar system, whereas Psyche will tell us about early terrestrial planet formation.

As in the summer 2015 New Horizon flyby of Pluto, the scientists have a basic idea of what to expect, but they also anticipate surprises. These missions will examine objects that have never been studied in such detail, and they intend to live up to the program's name: Discovery.

Elkins-Tanton hopes that the missions will move beyond even our scientific knowledge of the solar system to affect people around the world at a deeper level. "If it can inspire people to stand up and start solving problems that they are not now solving," she said, "that would be the greatest outcome."

By **Elizabeth Jacobsen,** Staff Writer

Geoscientist-Rich Crew Slated for Space Station Next Year

In spring 2018, an extraordinary crew is expected to assemble far above our planet on the International Space Station (ISS). The crew will include two geophysicists, which will make the group exceptional, said Drew Feustel, a seasoned astronaut with a Ph.D. in geological sciences who will serve as a flight engineer for the station's Expedition 55 and commander for its Expedition 56.

NASA

Geophysicists (left) Drew Feustel and (right) Alex Gerst train underwater for their off-world duties. Starting in spring 2018, they'll begin their 6-month stays on the International Space Station. The sign they are holding says "underwater geophysics."

Two geophysicists on one space station crew is hardly the norm. "I believe this will be the first time in history that two geophysicists will be in space together," Feustel told *Eos*.

Feustel will launch from Kazakhstan in March 2018 on a Russian Soyuz rocket, NASA announced on 4 January. Two months later, European Space Agency astronaut Alexander Gerst, a volcanologist, will join the crew and remain on the space station through November. Gerst will serve as commander for Expedition 57. Both he and Feustel are AGU members.

A third new crew member will make another kind of history. Jeanette Epps, an aerospace engineer and veteran technical intelligence officer for the U.S. Central Intelligence Agency (CIA), will become the first African American, man or woman, to join an ISS crew.

Doing Earth Science from Space

Although the official duties of the crew's geoscientists will be outside their research specialties, the scientists will still monitor the globe using Earth observation photography, Feustel said. Such images help geoscientists "study long-term changes in morphology of the Earth," he noted.

"I am honored to have the opportunity to visit space again and to have a chance to actually live there for nearly 6 months," Feustel added. He first soared into space in 2009 aboard the space shuttle *Atlantis* for the final servicing mission to the Hubble Space Telescope. He was also on the penultimate space shuttle flight in May 2011, that time on *Endeavor* (see http://bit.ly/eos-in-space).

"Returning to space means that I can continue to contribute to the exploration of the cosmos by humans and for humans," he continued.

Fulfilling a Dream

Epps will fly to the ISS in May 2018. Selected as one of nine out of 3500 applicants for NASA's 2009 class of astronauts, she will serve as a flight engineer for Expeditions 56 and 57.

When Epps was 9 years old, her older brother told her she was smart enough to be an aerospace engineer, even an astronaut. She went on to study physics at Le Moyne College in her hometown of Syracuse, N.Y., then aerospace engineering at the University of Maryland in College Park. After an engineering stint with the Ford Motor Company and 7 years at the CIA, Epps decided to apply in 2008 for NASA's then upcoming astronaut class.

By **JoAnna Wendel** (@JoAnnaScience), Staff Writer

Unifying Ocean Data into One Searchable Set

Ocean scientists will now find it easier to track deep-sea data from disparate sources: Introducing SeaView, a new central home for ocean data that strings together five online databases (see http://bit.ly/SeaView5).

The central idea of SeaView is to unify vast streams of data from different sets into one easily searchable set. The project, led by the Scripps Institution of Oceanography, is the ocean arm of a broader initiative called EarthCube. The latter effort is funded by the U.S. National Science Foundation and aims to design and develop the cyberinfrastructure—information systems, databases, software, and tools—needed to support Earth and planetary sciences in the coming decades.

Making data from various collections searchable under the same platform will help researchers who seek to transform data into knowledge. "We're trying to reduce the time to science," said Steve Diggs, data curator at Scripps.

Diggs and other Scripps scientists presented a poster that gave an overview of SeaView (see http://bit.ly/FM16SeaView) at the 2016 AGU Fall Meeting in San Francisco, Calif., in December. Earlier that day, SeaView officially launched online.

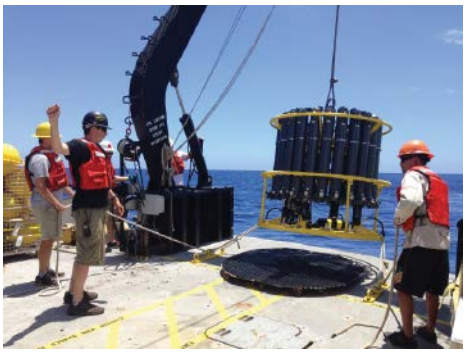
What If All Data Could Speak the Same Language?

SeaView pulls data from five databases: Rolling Deck to Repository (R2R), Ocean Observatories Initiative, Biological and Chemical Oceanography Data Management Office (BCO-DMO), Ocean Biogeographic Information System (OBIS), and CLIVAR and Carbon Hydrographic Data Office (CCHDO). Together they encompass data on biological, chemical, physical, and geological properties of the majority of the world's oceans.

To unify data from the different sources, researchers at SeaView first sought to understand why data have varied formats. Most of these sources are collections of data taken at sea by research cruises, moored sensors, and ocean gliders. Formatting differences in data strike at the nature of the research itself.

"Ships are interesting; they have different scientists on board who have different methods," said Diggs. "Right when they capture the data, [the data] start to look different." The same holds for data from moorings and gliders. Differences in project design often mean that similar data get formatted differently from project to project.

Further, once data are split off to be housed in different repositories, there's no way to bring them back together, explained Karen Stocks, director of the Geological Data Center at Scripps and the lead author of the poster. To help get around this, her group is now implementing standard identifiers, so that metadata from the same cruise or mooring network all get the same code. This will help data users down the line better understand where information came from.



Tara M. Clemente

Deploying conductivity-temperature-depth instruments from R/V Oceanus *for Hawaii Ocean Time-Series cruise 284 in May 2016.*

Building SeaView has helped the team understand what scientists need to do differently to make source data more easily integrated. They're now bringing that wisdom back to the original data warehouses so that they can start to standardize approaches to collecting data. Such consistency will help future data integration, which will ultimately help scientists find more patterns in the data, Stocks noted.

Data Themes: The Ocean North of Hawaii and the Gulf Stream

In addition to integrating data from the five online catalogs, researchers at SeaView are curating information for specific regions.

"We're not becoming a new data center that just takes the data from everybody else," said Stocks. "We're developing thematic collections about particular kinds of science that researchers are doing."

The team, working directly with ocean scientists to understand their priorities through a series of focus groups and workshops, identified two scientific areas of highest interest. One is in the Pacific Ocean north of Oahu, Hawaii, and the other is off the U.S. east coast, within the Gulf Stream.

"When we were selecting sites, we looked for places where there was a lot of science interest and a large enough set of data across the different repositories," Stocks explained. The team then collected data from each region into a unified set, so that "when you put it together, the whole may be greater than the sum of the parts."

Active, multidisciplinary ocean research is going on in both regions. The Hawaiian collection, for example, contains metadata from 278 cruises at R2R, data from 266 cruises at BCO-DMO, microbial data from the OBIS package, and data from 255 cruises at CCHDO. The Gulf Stream collection contains a similar volume of data.

The two specialized collections (see http://bit.ly/SeaViewData) contain data that scientists want integrated right now, Diggs explained. "There are many scientists developing new proposals to do new work" in the regions, Stocks added. "Having a broad set of accessible, usable data will help them develop new science ideas," she said.

Putting SeaView to Work

Efforts such as SeaView will help scientists effectively share data across disciplines, explained Stace Beaulieu, biological oceanographer at Woods Hole Oceanographic Institution. "Success is when we can integrate our own resources with others and get a better understanding of, in my case, marine ecosystems," she said.

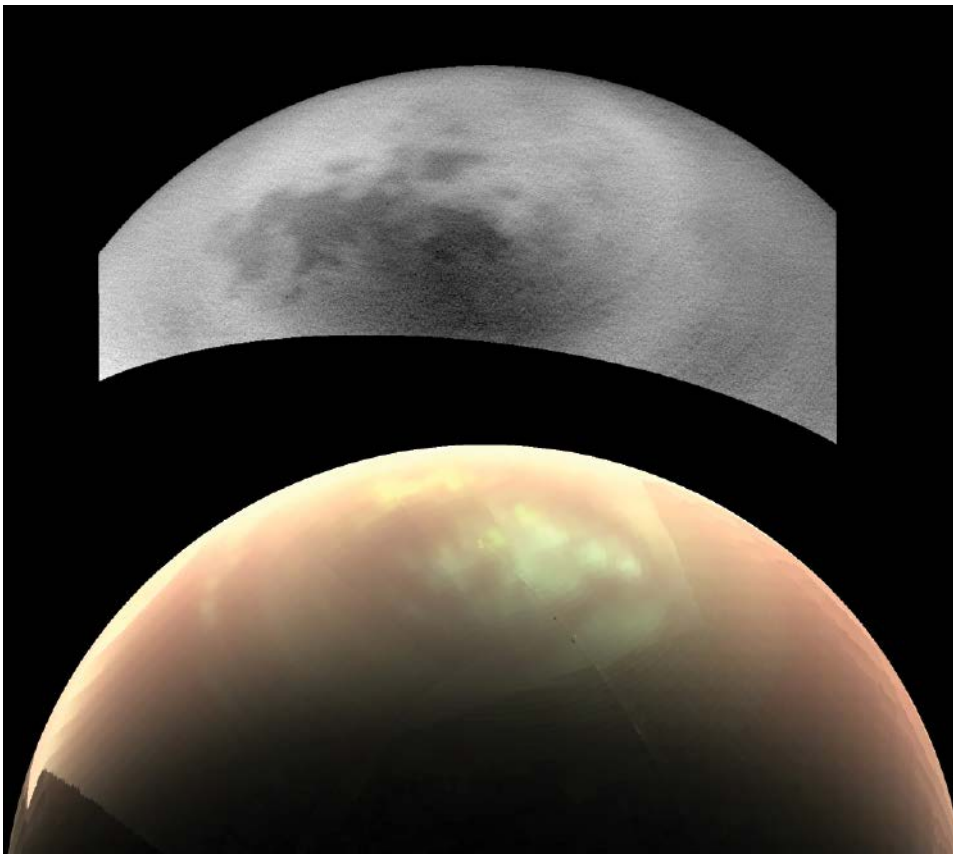
Beaulieu noted that the next challenge would be to effectively communicate SeaView output, so that scientists across disciplines can become aware of the integration happening at the repository level.

Ultimately, the goal is to render SeaView obsolete. "SeaView making these [integrations] for you shouldn't have to happen," Stocks said. "The repository should have everything clean and integrated to begin with."

Until then, however, SeaView is on hand to fill the gap.

By **Devika G. Bansal** (email: dgarg@ucsc.edu; @dgbansal), Science Communication Program Graduate Student, University of California, Santa Cruz

The Curious Case of Titan's Missing Clouds



NASA/JPL-Caltech/SSI/Univ. Arizona/Univ. Idaho

Titan's northern regions, imaged by two cameras aboard the Cassini spacecraft, show that one instrument can see clouds that the other cannot. (top) A view from the ISS camera, taken on 8 June 2016, shows relatively cloud free skies. (bottom) An image of the same region, taken a day earlier by the VIMS camera, shows a large bright field (yellow) of clouds.

We all know that a watched pot will boil eventually—it's the wait that's agonizing. For scientists studying Saturn's moon Titan, this wait is all too familiar.

Their boiling pot? Spotting storm clouds near the moon's northern pole. Every few days, when the Cassini spacecraft beams down a new image of Titan's northern hemisphere, the team eagerly checks for the fluffy features.

All models say that the storm clouds should have appeared by now, explained Elizabeth Turtle, a planetary scientist at the Johns Hopkins Applied Physics Laboratory in Baltimore, Md. "It's become this fun waiting game: When we get images, we look and we say, 'Are there clouds?'"

Clouds of Confusion

Studying Titan's clouds helps scientists better understand not only its atmosphere but also Earth's. Titan is the only other body in the solar system with Earth-like liquid cycling between rain and stable liquid surface features, which makes it a natural Earth analogue.

Instead of a water cycle, Titan has a methane cycle. The moon's average temperature hovers around a chilly 94 K (for comparison, the freezing point of water is 273 K). Methane condenses high in Titan's sky as clouds, rains onto the icy surface as a liquid, erodes the surface ice as it runs into lakes and rivers, and evaporates once again into the atmosphere.

And because Titan spins on a tilted axis, similar to Earth's, seasons affect the atmosphere in a similar way. During the summer, one pole is always sunlit and one pole is always dark. Warm temperatures on the more sunlit hemisphere cause convective storm cells to form, just as summer storms form on Earth.

When Cassini arrived at Saturn in 2004, Titan was in the middle of its "January"—northern winter, southern summer. Unsurprisingly, the Cassini team saw lots of southern summer storms.

Titan's year lasts almost 30 Earth years. In the past few Earth years, Titan's seasons have shifted, and we're just entering its "June," Turtle said. Ever since this shift began, scientists studying Titan have been waiting for the same summer storms to form in northern latitudes.

But as of mid-February on Earth, those storms and their clouds hadn't yet appeared in Turtle's images.

Last summer (on Earth), after Cassini's Imaging Science Subsystem (ISS) camera revealed yet another disappointingly stormless north, Turtle started to think that maybe their models were wrong. But then her colleague Jason Barnes, who works with Cassini's Visual and Infrared Mapping Spectrometer (VIMS) team, emailed to ask, "What'd you think of all those great clouds?"

Cloudy Day...or Not?

"What clouds?" was Turtle's first thought. She checked her images again and could clearly see all the surface features like lakes and rivers—none was obscured by clouds. But the VIMS images showed something different: a wide swath of bright, smudgy clouds obscuring the exact same surface features Turtle could see clearly from the ISS data.

With the ISS instrument, which "sees" light wavelengths in the near infrared between 980 nanometers and 1–2 micrometers, "we see one cloud, one little cloud, maybe 10 kilometers across," Turtle said. With the VIMS instrument, however, scientists can see through the visible spectrum and farther into the infrared to wavelengths that stretch to 5 micrometers. With those data, "it looks like there's this wide expanse of clouds," she said.

"We were already taking it personally that the clouds aren't showing up," Turtle said lightheartedly. "And then to add insult to injury, now they're only showing up in some wavelengths, but not at others?"

It seemed that a science mystery was afoot.

Cirrus-ly Weird

Turtle presented this puzzler at the 2016 AGU Fall Meeting in San Francisco, Calif., in December (see http://bit.ly/FM2016Titan).

What made this mystery especially odd, she explained, was that if one instrument was going to miss the clouds, it should have been VIMS. This is because the tiny particles of liquid, ice (whether methane or water), and dust that make up clouds scatter short wavelengths of light—that's why we can see clouds on Earth. So VIMS, which sees in longer wavelengths, should be able to penetrate right to the moon's surface.

First, Turtle and her team confirmed that the two instruments took pictures of the same location. Next, she wondered whether the clouds could be floating over relatively bright terrain and that's why the ISS instrument missed them. But that wasn't the case because the ISS images clearly showed the darker lakes and seas in the same places that VIMS saw clouds.

Finally, the researchers considered altitude, and the VIMS team ran models to determine the possible height of the clouds. These models revealed that the clouds hovered 40 kilometers above Titan's surface, right at the top of its troposphere. These clouds were probably very thin and wispy, like cirrus clouds on Earth.

Turtle hypothesized that Titan's atmospheric haze, formed by all the methane in its atmosphere, could be thick enough to obscure the cirrus clouds from the ISS's view. After all, "if there were high clouds on a smoggy day on Earth, you wouldn't be able to tell," Turtle said.

Seeing Clearly Now

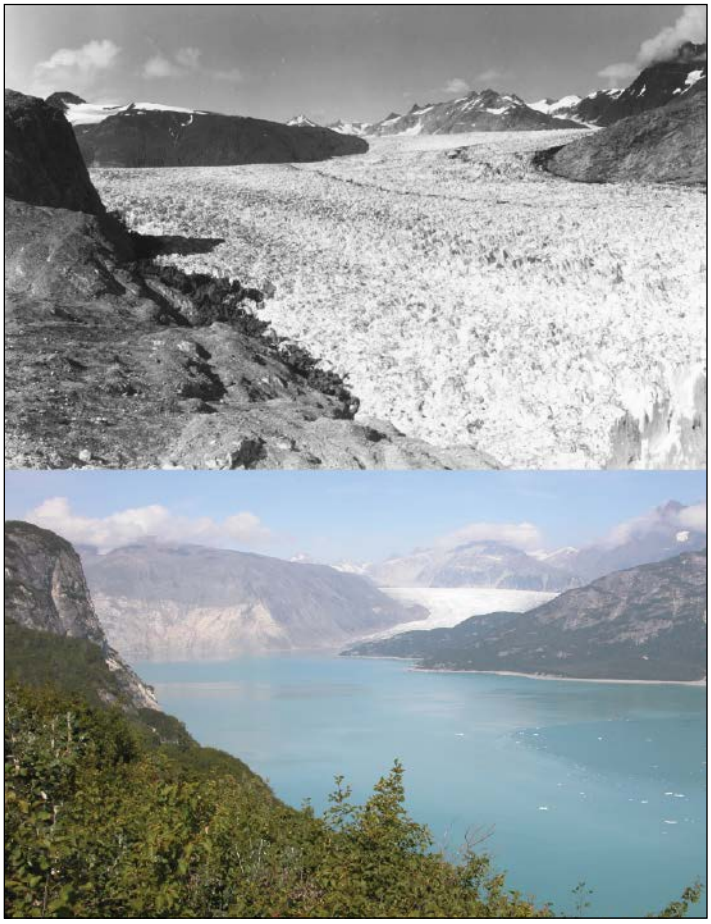
High-flying cirrus clouds are, for now, the best explanation the Cassini team can come up with, and they've tasked some graduate students to start digging through old ISS and VIMS data to see whether this kind of discrepancy has ever happened before. Meanwhile, the researchers are still hunting for large storm cells.

Mysteries like this one are important because they fuel discovery, explained VIMS team member Robert Nelson of the Jet Propulsion Laboratory in Pasadena, Calif. "We've got two instruments that measure the same thing in different ways, and we see something different," he said. "That's exciting because when we resolve the differences between the instruments, we learn something more about the physics of what's going on" on Titan.

After 125 flybys over 12 years, "the fact that Titan can still surprise us was pretty exciting," Turtle said.

By **JoAnna Wendel** (@JoAnnaScience), Staff Writer

Award Highlights Need to Preserve Historic Geoscience Data



(Top) William Osgood Field/NSIDC; (bottom) Bruce F. Molnia/USGS

Two photographs of Muir glacier in Alaska showing the extent of landscape change, both from the Glacier Photograph Collection in the Roger G. Barry Archive at the National Snow and Ice Data Center in Boulder, Colo. (top) A 1941 photo and (bottom) a 2004 photo taken from the same location. A project to digitize the archive received the 2016 International Data Rescue Award in the Geosciences.

The preservation of Earth and space science data took on even more urgency and relevance at a recent awards ceremony.

The 2016 International Data Rescue Award in the Geosciences, presented during a town hall meeting at the 2016 AGU Fall Meeting in San Francisco, Calif., in December, went to a team of researchers working to digitize and preserve historic snow and ice data. These data include historic imagery of glaciers that have since changed dramatically (see http://bit.ly/2016-data-rescue).

The award winner was announced just 2 days after news broke that some other scientists are frantically copying unrelated U.S. government climate data out of their fear that the data could vanish during the Trump administration (see http://bit.ly/DataAtRisk). That fear is based in the idea that some likely appointees are climate science skeptics.

"Hearing what is going on right now about data rescue and the fear that data might disappear—I'm very concerned," said Kerstin Lehnert, director of the Interdisciplinary Earth Data Alliance (IEDA) and senior research scientist at the Lamont-Doherty Earth Observatory of Columbia University, located in Palisades, N.Y. IEDA and Elsevier Research Data Services organized the award, and Lehnert spoke to *Eos* at the data rescue award's presentation ceremony.

Lehnert, who is also the current president of AGU's Earth and Space Science Informatics (ESSI) focus group, stressed the importance of data preservation. Scientists need "to make sure that the record of the science and the record of observations we do in the Earth sciences are kept for future research and future science," she said.

The Winning Project

The winning project, "Revealing Our Melting Past: Rescuing Historical Snow and Ice Data," is an effort to digitize the Roger G. Barry Archive at the National Snow and Ice Data Center (NSIDC) at the University of Colorado Boulder (http://bit.ly/NSIDCBarry). The

(Top) Louis H. Pedersen/NSIDC; (bottom) Bruce F. Molnia/USGS

Two photographs of the Pedersen glacier in Alaska, showing the extent of landscape change. (top) A 1917 image. (bottom) A 2005 image taken from the same location. Both images are part of the Glacier Photograph Collection in the NSIDC archive.

archive is a trove of snow and ice data in many formats, including prints; images on microplates and glass plates; ice charts from early expeditions to Alaska, the Alps, South and Central America, and Greenland; and handwritten 19th-century exploration diaries and observational data.

"This is a project that is all about rescuing glacier photos that go all the way back to the late 1800s," said Ruth Duerr, a project team member who represented the group at the award ceremony. "For science, it is giving you a 150-year record of individual glaciers around the world and how they have changed in terms of mass lost or gained; mostly lost," said ESSI president-elect Duerr, a research scholar in science data management and software and system engineering at the Ronin Institute for Independent Scholarship, which is based in Montclair, N.J.

The project, submitted for the award by Jack Maness, associate professor and director of sciences at the University Libraries at the University of Colorado Boulder, has so far focused on digitizing historic glacier photograph prints, which Lehnert said are fragile, valuable, and unique. The photographs contain rich information on glaciers, permafrost, sea ice, and related data for time periods predating the satellite and digital era, she noted.

The images "are essential to the study of climate change over time and a rich source for the study of our planet and the history of science and exploration, extending our window of analysis," Lehnert told *Eos*.

Other institutions involved in the project include NSIDC, the National Oceanic and Atmospheric Administration, the University of Illinois at Urbana-Champaign, and the Denver Botanic Gardens.

Using the Archive

One researcher who has delved into the NSIDC archive of glacier photos is Bruce Molnia, senior science adviser for national civil applications with the U.S. Geological Survey in Reston, Va. He has taken updated images of some of the same glaciers that are represented in the NSIDC collection. Some of his images were taken up to 125 years after the original photographs.

Molnia told *Eos* that his goal was to provide to the archive comparative images of glaciers so that viewers could clearly see the extent of landscape change. He said that almost every pair of photos shows the transformation of the landscape from white glaciers and dark bedrock to green, heavily vegetated land surfaces and abundant blue water.

"The importance of the NSIDC historical glacier photo collection is paramount," he said. The collection "is one of a very limited number of venues where an image scientist, or anyone, for that matter, can find a rare window into the appearance of Earth's past landscapes that were dominated by glaciers."

Raising Awareness of Historic Data

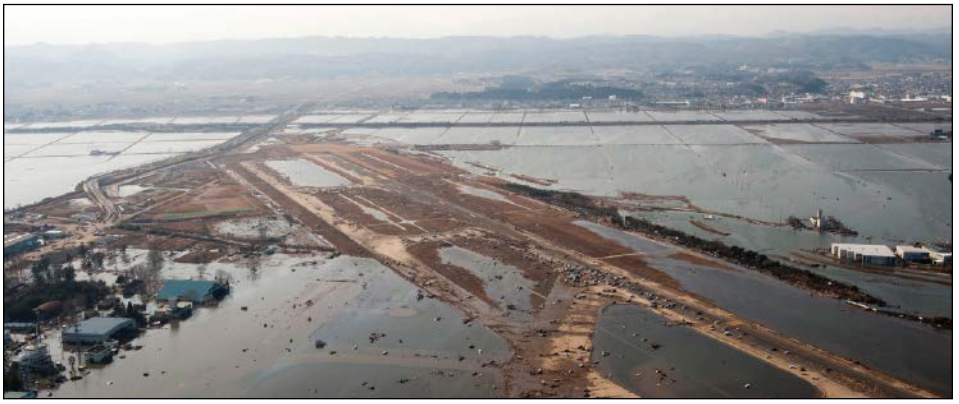
The data rescue award, presented for the first time in 2013, was created to raise awareness about the importance of preserving and having access to historic research data. The award also aims to increase the prospects for preserving the data and showcase the diversity of techniques that can be adopted to recover and reuse older research data, according to Elsevier, a provider of scientific, technical, and medical information products and services.

Historic data at risk could include material that is fragile, has a poor preservation outlook, exists only in hard copies that may not be properly indexed and archived for convenient access and retrieval, or is stored in older electronic formats that may be difficult to retrieve.

Along with the award, the team received a $5000 check, which Duerr said will be used to further preservation efforts that could lead to more use of the archive's materials. "People have a hard time seeing change over their lifetimes," she said about the historic and modern photos. Now "they can see change over their and their grandparents' lifetimes."

By **Randy Showstack** (@RandyShowstack), Staff Writer

Tsunamis Leave a Telltale Chemical Trail



Staff Sgt. Samuel Morse/U.S. Air Force

After a magnitude 9.0 earthquake in March 2011 unleashed a tsunami near the east coast of Honshu, Japan, debris and water covered most of the nearby Sendai Airport. A team of researchers tracked the path of this tsunami by following a trail of organic compounds in the soil, a method they hope to use to track other past tsunamis.

When large tsunamis sweep up on coastlines, they're often deadly: The 2004 Indian Ocean tsunami and the 2011 Tohoku tsunami in Japan were responsible for nearly 250,000 fatalities. Raising awareness of these lethal waves and improving evacuation routes are key to minimizing death tolls in tsunami-prone regions such as the U.S. Pacific Northwest, Japan, and Chile.

"The primary goal of tsunami research is to prepare regions for future tsunami, particularly in areas where the recurrence interval between tsunami is longer than one generation and knowledge of the hazard can become lost," said Piero Bellanova, a graduate student in the Neotectonics and Natural Hazards Group at Rheinisch-Westfälische Technische Hochschule Aachen (RWTH Aachen University) in Germany.

He and his collaborators have now shown that data from the humblest of geological field samples—soil—can reveal when and where historic tsunamis moved over land. By dating trace pollutants swept on land from previous tsunamis and effectively reconstructing their path, researchers can calculate the approximate intervals between tsunamis and determine their movement inland. This information can be used to raise awareness of the waves and improve the safety of evacuation routes, Bellanova suggested at a poster session at the 2016 AGU Fall Meeting in San Francisco, Calif., in December (see http://bit.ly/tsunami-tracers).

Fuels, Fats, and Plastics

The research team, led by Klaus Reicherter and Jan Schwarzbauer at RWTH Aachen University, collected soil samples in 2013 from seven sites around the Sendai Plain and the Sanemoura and Oppa bays of Japan that experienced heavy damage from the 2011 Tohoku earthquake and tsunami. "It's important for tsunami scientists to go into the field," Bellanova said.

They isolated soil laid down before, during, and after the tsunami. Then they analyzed the chemical composition of each sample, focusing on the relative abundances of fuels, fats, and plastics that commonly make up industrial pollutants and on pesticides.

The researchers showed that some of the compounds were significantly more concentrated in the sandy soils deposited during the tsunami, consistent with industrial debris being transported inland by a series of tsunami waves. Researchers can determine the flow direction of the water by mapping out the diminishing concentrations of specific compounds at increasingly distant locations from the shoreline, Bellanova explained.

It's a simple idea but a relatively new technique. "Organic geochemistry has not yet become a focus of the tsunami community," said Bellanova. "We need more information about a tsunami than just its appearance."

A Three-Dimensional Picture

Bellanova and his colleagues contend that their technique is preferable to aerial photography, which is commonly used to map tsunami flow. "Aerial images are very useful, but you will always gain more information by seeing the deposits in three dimensions," said Bellanova. "With field data you can tell something about the run-up height and the actual water level during a tsunami."

In addition, obtaining the personnel, aircraft, and equipment necessary for aerial photography can be difficult and prohibitively expensive, particularly in resource-poor settings or areas suffering from widespread damage. Airborne images must also be acquired relatively soon after a tsunami, before the natural setting has recovered and before buildings have been rebuilt.

Soil samples, on the other hand, can be reliably collected years after the obvious signatures of a tsunami have vanished. These samples can be analyzed at laboratories safely situated away from the scene of the disaster.

Nonetheless, there's a potential limitation of soil sample analysis, noted Christopher Vane, a geochemist at the British Geological Survey in Keyworth, U.K., who was not involved in the study. "It won't work in settings where there has been continual industrial output because the pre-tsunami sediments will contain the same anthropogenic compounds as the tsunami sediments," he said.

An Archaeological Mystery

Bellanova and his collaborators are now using soil sample analysis to investigate an archaeological mystery: Between the 2nd and 4th centuries CE, Spanish and Portuguese fishing production decreased dramatically, but no one knows precisely why. Historical records indicate that a massive tsunami pummeled the region in 1755, and some scholars have suggested that another tsunami might also have decimated the coastline hundreds of years earlier. "We want to work further back in time and try to identify chemical compounds in even older deposits," Bellanova said.

The team is betting that soil samples can successfully solve this archaeological puzzle. Bellanova and his colleagues have already collected soil in Spain and Portugal and will return later this year to gather more. They'll be looking for increased concentrations of organic compounds typical of that era, like fish oil and tannery runoff. If they find them, the researchers can begin to piece together the tsunami history of the Spanish and Portuguese coastlines, paving the way for similar studies in other parts of the world.

By **Katherine Kornei** (email: hobbies4kk@gmail.com), Freelance Science Journalist

Honoring Earth and Space Scientists

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Prince Sultan Bin Abdulaziz International Prize for Water

On 2 November 2016, at the United Nations Headquarters in New York, the 7th Awards Ceremony for the Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW; http://www.psipw.org) recognized several researchers whose work addresses water scarcity in innovative ways. HRH Prince Khaled Bin Sultan announced the winners of the 2016 Creativity Prize and other PSIPW awards on 5 October 2016.

The Creativity Prize honored two teams of researchers for their water scarcity work. **Rita Colwell** of the University of Maryland, College Park, and **Shafiqul Islam** of Tufts University received the prize for developing a model to predict cholera outbreaks as early as 6 months in advance. Their method uses chlorophyll information from satellite data to make these predictions. **Peter J. Webster** of the Georgia Institute of Technology was selected for his research on monsoon strength. His work on ocean–atmosphere interactions has made it possible to forecast monsoonal floods as early as 1 or 2 weeks before they strike.

Other PSIPW awards include the Surface Water Prize, awarded to **Gary Parker** of the University of Illinois at Urbana–Champaign. The Groundwater Prize was awarded to **Tissa H. Illangasekare** of the Colorado School of Mines. The Alternative Water Resources Prize recognized **Rong Wang** and **Anthony G. Fane** of Nanyang Technological University in Singapore, and **Daniel P. Loucks** of Cornell University received the Water Management and Protection Prize.

Mineralogical Society of America Distinguished Public Service Award

Last October, **David Mogk,** a metamorphic petrologist at Montana State University in Bozeman, received the 2017 Mineralogical Society of America (MSA) Distinguished Public Service Medal (see http://bit.ly/MSA-award). Mogk has long been interested in educational outreach in the geosciences. He served a term as program officer at the National Science Foundation's Division of Undergraduate Education, and he has been involved with geoscience education programs such as On the Cutting Edge and Bringing Research on Learning to the Geosciences. The 2000 AGU Excellence in Geophysical Education Award also recognized Mogk's outreach efforts.

Society of Exploration Geophysicists President-Elect Announced

Nancy House assumed her position as president-elect of the Society of Exploration Geophysicists (SEG; http://seg.org) for the 2016–2017 term after SEG's 2016 annual meeting on 16–21 October in Dallas, Texas. SEG announced its selection of House last summer. House will become SEG president after SEG's 2017 Annual Meeting, which will be held in Houston, Texas, in September. She will be the second woman to serve in that office since SEG was founded in 1930.

The 2016–2017 SEG board of directors includes several other newly elected members, including **Madeline Lee** (second vice president), **M. Lee Bell** (treasurer), and **Paul Cunningham** and **Ruben Martinez** (directors at large). Incumbents rounding out the board are **Bill Abriel** (current president); **Jie Zhang** (first vice president); **John Bradford** (past president); **Mauricio Sacchi** (editor); **Maurice Nessim**, **Xianhuai Zhu**, **Rocco Detomo Jr.**, and **Vladimir Grechka** (directors at large); and **Lee Lawyer** (chair of the SEG Council).

L'Oréal USA 2016 For Women in Science Fellows

L'Oréal USA announced the recipients of the 2016 For Women in Science Fellowship, which grants as much as $60,000 apiece to women scientists to be applied toward their postdoctoral research. The fellowship, whose recipients were announced on 26 September 2016, recognizes women for their contributions to the advancement of science and for their commitment to supporting women and girls in science, technology, engineering, and math (STEM) fields.

Among five fellows announced by L'Oréal USA was one earth scientist, **Anela Choy,** a postdoctoral fellow at the Monterey Bay Aquarium Research Institute, who will use her fellowship to continue her research into ocean food webs and how pollution and environmental change affect them. **Shruti Naik**, a postdoctoral scientist at Rockefeller University, also received the award to conduct interviews with prominent women scientists as part of a project to inspire girls and women interested in pursuing STEM careers. For the full list of fellows, visit http://bit.ly/Loreal-fellows.

MacArthur "Genius Grants"

The MacArthur Fellows Program awards fellowships to individuals who show a history of accomplishment that foreshadows continued advances and who demonstrate creativity in their work. The John D. and Catherine T. MacArthur Foundation announced its 2016 awardees in September. Among them were two geobiologists at the California Institute of Technology: **Dianne Newman,** a professor of biology and geobiology, and **Victoria Orphan,** a professor of environmental science and geobiology. See the full list of fellows at http://bit.ly/MacArthur-fellowships.

Council on Undergraduate Research Fellows Award

Jill Singer of the State University of New York–Buffalo State and **Jeffrey Osborn** of The College of New Jersey both received the Council on Undergraduate Research (CUR) Fellows Award (see http://bit.ly/CUR-Fellows). The CUR Fellows Award recognizes their research, in particular, their programs involving undergraduate students. Both Singer and Osborn have encouraged undergraduate research at their institutions and at the national level.

The Pace of Change on Tropical Landscapes

Chapman Conference on Emerging Issues in Tropical Ecohydrology
Cuenca, Ecuador, 5–9 June 2016

Diego Cupolo CC BY-NC 2.0 (http://bit.ly/ccbync2-0)

A trail meanders through Puerto Rico's El Yunque National Forest, the only tropical rain forest in the U.S. National Forest System. An AGU Chapman Conference last June examined the current understanding of tropical ecohydrology, identified critical research needs, and promoted interdisciplinary collaboration.

Tropical landscapes account for about one fifth of the global landmass. They are the source of most of the Earth's streamflows, and they influence climates on regional and global scales. But the characteristics that distinguish tropical ecosystems from nontropical ones—stronger gradients, faster processes, and greater variability, to name a few—also pose unique challenges to ecohydrologic investigations.

In addition, the dual processes of climate change and deforestation are driving rapid changes in landscapes in tropical latitudes. The effects of these changes on water and biogeochemical processes, at a range of scales, are enormous but poorly understood. Scientists do know, for example, that deforestation leads to changes in evapotranspiration, streamflow, and precipitation on local to regional scales and may even influence global climates. Similarly, climate change will likely lead to large-scale and important changes in cloud and precipitation dynamics, feedbacks between the atmosphere and vegetation, and hydrologic cycles in the tropics.

A Need for Greater Understanding

Given the accelerated pace of change, the importance of tropical landscapes, and scientists' relatively poor understanding of tropical ecohydrology, hydrologists Bradford Wilcox, Jeff McDonnell, Heidi Asbjornsen, David Breshears, and Rolando Celleri organized an AGU Chapman Conference to focus on these critical issues (see http://bit.ly/Chapman-ecohydrology). The June 2016 meeting drew more than 115 academics, research scientists, and early-career professionals from around the world.

The conference was organized around three themes: the relationship between plant physiology and watershed hydrological functioning, scaling issues, and land degradation and rehabilitation and recovery.

The conference fulfilled two main goals, one of which was examining the current understanding of tropical ecohydrology and identifying critical research needs. The other goal was to foster greater interdisciplinary collaboration across the spectrum of ecological and hydrological sciences, in particular, between ecophysiologists and catchment hydrologists.

> The dual processes of climate change and deforestation are driving rapid changes in tropical landscapes.

Abundant Opportunities

There are tremendous opportunities to better link ecohydrology with ecophysiology in the tropics, especially with regard to collecting empirical data from the field. Currently, the two areas of research are still worlds apart, and they have limited collaboration.

Conference attendees recommended adopting a strategy that balances long-term data collection with strategically targeted experiments. Participants also agreed that studies comparing watersheds could be of great value. Another recommendation was that researchers in the tropics be especially sensitive to the need for collecting information that is broadly relevant and that can be used to aid decision making.

Attendees devoted considerable discussion to the "two-water worlds" hypothesis and whether it is applicable to tropical landscapes. The hypothesis states that tightly bound water in deep soils has little interaction with mobile water in surface soils and streams. Many researchers argued that this hypothesis holds great promise for better understanding the ecohydrology of the tropics, whereas others maintained that supporting evidence may be an artifact of current

Bradford P. Wilcox

The Andean Páramo zone is a vital source of water for Andean countries. The Chapman Conference featured a field excursion to view the University of Cuenca's research efforts in this high-elevation grassland in the tropics.

sampling techniques. Participants agreed that the topic merits further research.

During breakout meetings, participants challenged one another to develop joint papers synthesizing important and emerging areas in tropical ecohydrology. Discussions identified several potential themes for further development and subsequent publication in a special issue. These themes included issues related to ecosystem disturbance, exotic plant invasions, soil faunal effects on soil hydrological functioning and runoff generation, and optimal data collection strategies.

The poster sessions emerged as a popular feature, with presentations from many early-career scientists, mostly from Latin America. Discussions during this part of the conference were especially lively and stimulating. Another highlight of the conference involved a field excursion to view the University of Cuenca's research efforts in the Andean Páramo zone, a high-elevation grassland.

A Meeting of the Minds

Arguably, the most important outcome of the conference was the bringing together of so many scientists, especially young scientists, from across the globe and enabling them to forge what will likely be long-lived and productive relationships. As one attendee remarked, "I believe the social value of this meeting will endure as one of its greatest accomplishments."

About 40 of the early-career scientists attended thanks to support from the National Science Foundation, the U.S. Department of Energy, and the University of Cuenca.

By **Bradford P. Wilcox** (email: bwilcox@tamu.edu), Texas A&M University, College Station; **Sampurno Bruijnzeel,** King's College London, London, U.K.; and **Heidi Asbjornsen,** University of New Hampshire, Durham

Developments in the Study of Rock Physics

SEG/AGU Workshop: Upper Crust Physics of Rocks
Hilo, Hawaii, 11–14 July 2016

Reza Malehmir

An evening view of the eruptions within the Halemaʻumaʻu crater in the Kīlauea volcano summit caldera. A July 2016 workshop on rock physics included a field trip to Hawaiʻi Volcanoes National Park, where an attendee took this picture.

The study of rock physics continues to grow rapidly in importance as geophysicists strive to provide more complete interpretations of geophysical observations using increasingly advanced data acquisition methods. A meeting last summer provided a timely venue for a review of the state of the science from an assortment of leading practitioners.

AGU and the Society of Exploration Geophysicists (SEG) have in the past few years promoted a series of jointly organized meetings to bring together scientists who might not normally interact but who share many common interests and research goals. The latest of these collaborations was a rock physics workshop held in Hilo, Hawaii, last July (see http://bit.ly/rock-physics).

The conference drew 56 scientists from Europe, Asia, Australia and New Zealand, and North America. Attendees covered a wide range of specialties and included those who focus on metamorphic, magma system, and sedimentary rocks, as well as those who use experimental, theoretical, and modeling approaches.

> The venue provided an exceptional opportunity to see rock physics in action.

The meeting was organized around six themes that centered on tectonics, rock physics theory and modeling, experimental developments, fractures and transport properties, evolving rock systems, and rock microstructure. Each session began with presentations from invited speakers providing overviews of their recent research. These were followed by "speed geeking"–style presentations: Each poster presenter gave a 4-minute talk to prepare attendees for the open poster session.

Discussions revolved around advancements in four realms: fundamental understanding of permeability through matrix and fracture networks, the modeling of geophysical responses at differing scales, the deformation of rocks in the brittle and ductile regimes, and the study of elastic dispersion (the speeds at which various frequencies of seismic waves travel through rocks saturated with fluids) from seismic to ultrasonic scales. This latter topic has experienced rapid growth in recent years.

Participants learned about a variety of new experimental and numerical tools that allow researchers to probe material structure and physical properties, illustrating some of the directions that rock physicists will take in the coming decade. Examples of rock physics applications for the interpretation of field geophysical data showed the necessity of having a better understanding of rock physics in geophysical monitoring for hydrocarbon and carbon sequestration.

The venue provided an exceptional opportunity to see rock physics in action by way of a field trip to the Hawaiʻi Volcanoes National Park. The field trip included a visit to the U.S. Geological Survey's (USGS) Hawaiian Volcano Observatory, hikes through lava tubes, and an after-sunset viewing of the glow from the active lava lake in Kīlauea Iki, a pit crater near the main Kīlauea summit caldera.

We owe special thanks to SEG expediter Jill Abbott, the workshop technical committee, and scientists at the USGS Hawaiian Volcano Observatory. We also thank the SEG Foundation for providing six student scholarships to assist with travel expenses.

A special collection of the *Journal of Geophysical Research: Solid Earth* is now being compiled to capture an up-to-date snapshot of the field of rock physics. This collection will include contributions from the workshop presenters, but we also enthusiastically encourage contributions from researchers who were not able to attend the conference. The submission deadline is 31 March 2017, and a description of the collection and direct submission link are available on the journal's "Rock Physics of the Upper Crust" web page (http://bit.ly/JGR-rock-physics).

By **Ludmila Adam,** School of Environment, University of Auckland, N. Z.; and **Douglas R. Schmitt** (email: dschmitt@ualberta.ca), Institute for Geophysical Research, Department of Physics, University of Alberta, Edmonton, Alb., Canada

Seven Projections for Earth and Space Science Jobs

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"Prediction is difficult, especially about the future."

—*Niels Bohr*

The year 2017 promises to be a time of political turbulence and change. New leaders have been elected or have come to power by other means in several countries. Conflict rages in many regions, and the global economy continues to equilibrate. In the United States and most European countries, large portions of the population are pushing back against social and economic changes that they perceive to be in their disfavor, resulting in protectionism and opposition to globalization.

What do these political and socioeconomic changes mean for the job market?

In the short term, probably not much. Employment rates in the United States this year should stay about the same as in 2016 because we expect the U.S. gross domestic product (GDP) to stay about the same.

In the decade to come, though, a few employment trends are likely. Here are seven things to expect as the future unfolds.

1 No Huge Employment Changes Are Likely in the United States in 2017

Yes, there will be much political rhetoric and many governmental and policy changes in 2017. However, governments and bureaucracies are built to protect the status quo, not to promote change.

In economics, the relationship between unemployment and economic growth is described by Okun's law. Arthur Okun, a former chair of the Council of Economic Advisors (1968–1969) and a Yale economist, found that for every 1% increase in a country's unemployment rate, there is an approximately 2% fall in the country's GDP.

> Employment rates in the United States this year should stay about the same as in 2016.

Major economists—from Forbes, Goldman Sachs, Edward Jones, and Wallet Hub—predict that the U.S. GDP will continue modestly upward at a feeble pace toward a growth target of 2.2% to 2.5% in 2017 (see, e.g., http://bit.ly/ForbesForecast).

Although that is nothing to party about, it is not apocalyptic. Thus, we can predict a steady state for U.S. employment, in accordance with Okun's law.

2 Trends in Other Countries May Not Be Applicable to the United States

European economies will continue to improve slowly throughout 2017, as will most of the emerging economies, including China (see http://bit.ly/GSOutlook). Economic growth in China is predicted to slow but will likely meet its published goal of 6.5% for its GDP (see http://bit.ly/MKChinaOutlook).

But it's important to note that employment statistics for most other countries are not directly comparable to ours. Granted, employment in Europe is expected to increase modestly, but employment is not easily defined for developing economies where independent subsistence is more common than working for money or for communist countries in which, technically, everyone is employed.

3 People with Advanced Degrees Will Fare Better

The average 2015 unemployment rate for Ph.D.s in the United States was 1.7%, and the rate for people with a high school diploma or less was 8.0%. The overall average unemployment rate for 2015 was 4.3%, which is about as good as it gets for the general population.

So, similar to in past years, those with a higher-education degree had much less unemployment and made more money than those without one. (Insert sigh of relief.) People with advanced degrees, especially in the Earth and space sciences, fared particularly well (see Table 1).

Those years of study to gain an advanced degree really were worth it in the end.

Although the full accounting of data isn't in yet, 2015 trends likely continued in 2016. The U.S. unemployment rate was 4.7% in December 2016.

I have received many questions from job seekers about the way-too-common perception that people with advanced degrees have a harder time finding employment than those with lower-level degrees. As can be seen from Figure 1, the higher the level of degree attainment is, the lower the unemployment level is.

In the Great Recession of 2008, when the U.S. manufacturing sector lost more than 2.7 million jobs, 1.6 million were lost by people with a high school diploma or less. In the economic recovery that followed, people with no college training gained back only 214,000 jobs out of the total 1.7 million created (see http://bit.ly/EconValueCollege). Many workers in lower-skilled jobs were replaced by technological efficiencies: robots, drones, and algorithms.

Without a doubt, the recession created an even greater divide between those with a high school diploma or less and those with at least

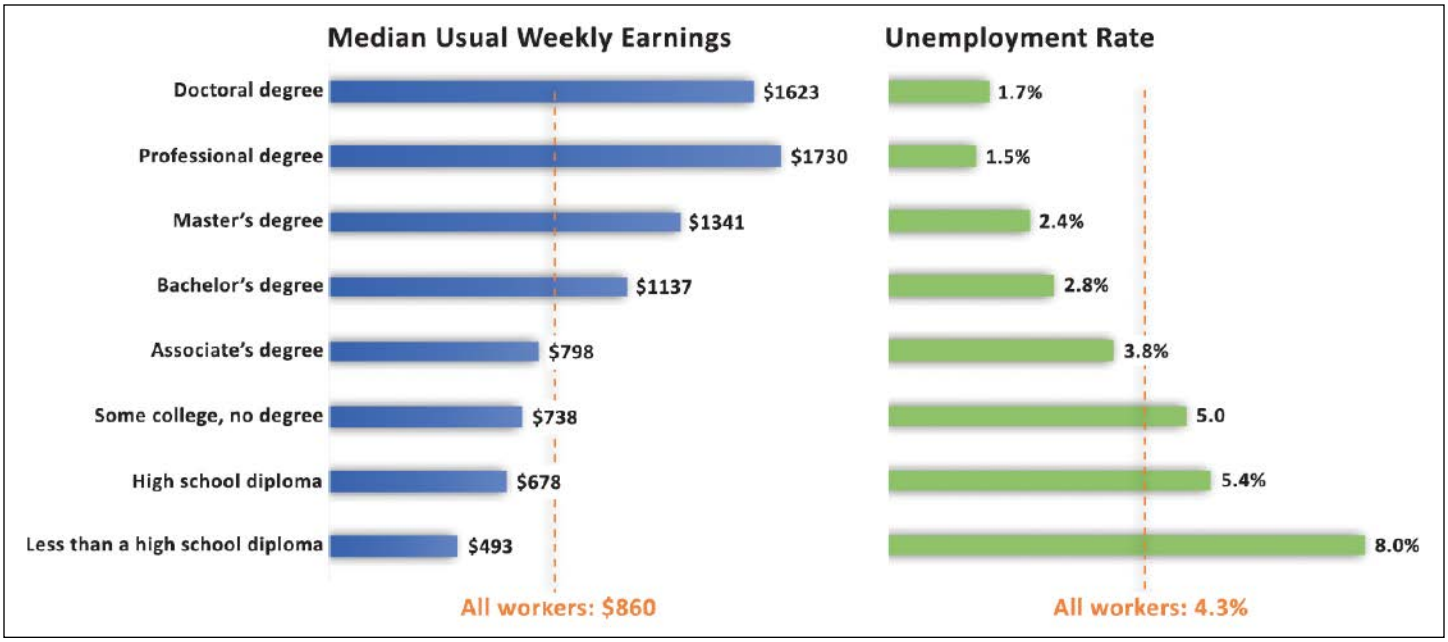


Fig. 1. Earnings and unemployment rates by educational attainment for 2015. Data are for persons age 25 and over. Earnings are for full-time wage and salary workers.

some college education. I offer this as further proof that a college education is necessary for success in the modern economy.

4 Earth and Space Science Employment: Cloudy, with a Silver Lining for Some

The employment outlook for the Earth and space sciences is still quite good compared with most professions. Both the U.S. Bureau of Labor Statistics and the American Geosciences Institute predict high demand in most fields (see http://bit.ly/BLSscience and http://bit.ly/AGIEmployment).

However, these employment reports were compiled prior to the 2016 election. Thus, predictions related to jobs in energy and environmental monitoring, regulation, and policy are likely inflated, especially for government agencies and academic positions. The current administration is, instead, leaning heavily toward practices and policies that favor U.S. businesses.

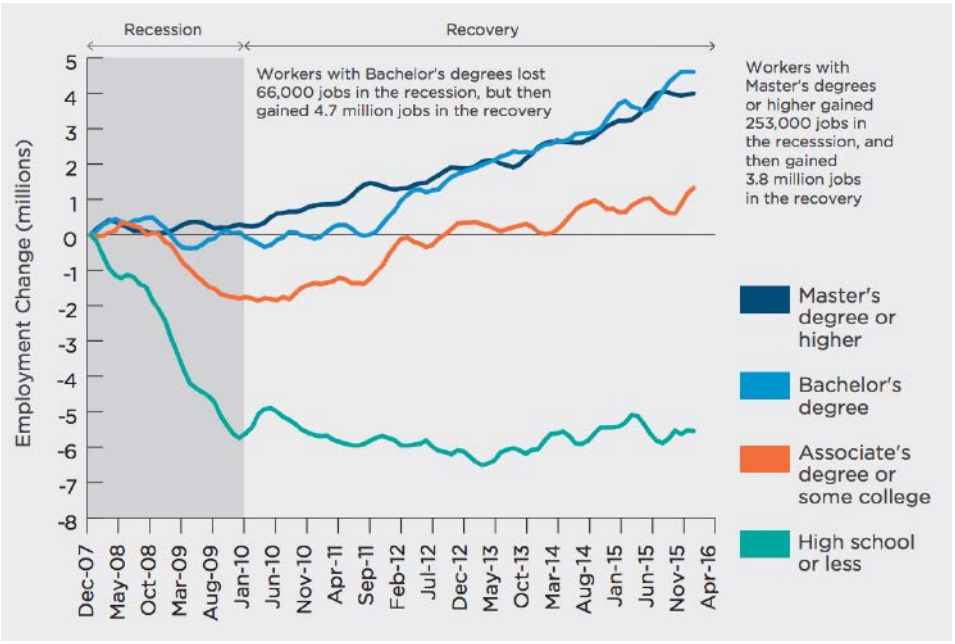
With that in mind, it's very possible that federal funding for climate change research could take a hit, which would affect not only federal agencies but also the university researchers who depend on that funding. It is possible that private foundations and industry may offer some measure of safety in the coming storm.

Taking shelter with state agencies may be a mixed bag. Already, some states, such as California, are vowing to step in to support climate change research regardless of what the federal government does. However, other states have been feeling a squeeze in all areas of geoscience research for some time now (see http://bit.ly/Eos-StateBudgets).

5 Government Jobs Will Start to Be Privatized

Business-oriented administrations favor the use of private companies for operations and services traditionally provided by government agencies. This does not necessarily mean that the net need for specific services will go down.

For example, although some regulations may be lifted for private businesses, there will still be a need for environmental specialists in many fields. Most large companies are global and thus will still need to meet regulatory policy requirements in all of the countries in which they have operations and



Employment data from 2007 to 2016, separated by education level. Employment includes all workers age 18 and older. The monthly employment numbers were seasonally adjusted using the U.S. Census Bureau X-12 procedure and smoothed using a 4-month moving average.

Table 1. Occupational Outlook and Salaries for Selected Earth and Space Science Occupations[a]

OCCUPATIONS	REQUIRED ENTRY-LEVEL EDUCATION	2015 MEDIAN SALARY (US$)	PROJECTED GROWTH RATE: 2014 TO 2024
Astronomers	doctorate	$111,000	7%, average
Atmospheric scientists, including meteorologists	bachelor's	$90,000	9%, above average
Chemists	bachelor's	$73,000	3%, below average
Environmental scientists	bachelor's	$67,000	11%, above average
Geoscientists, except hydrologists	bachelor's	$90,000	10%, above average
Hydrologists	bachelor's	$80,000	7%, average
Mining and geological engineers	bachelor's	$94,000	6%, below average
Petroleum engineers	bachelor's	$130,000	10%, above average
Professors	doctorate	$72,000	13%, above average
All physical scientists		$76,000	
All occupations		$36,000	

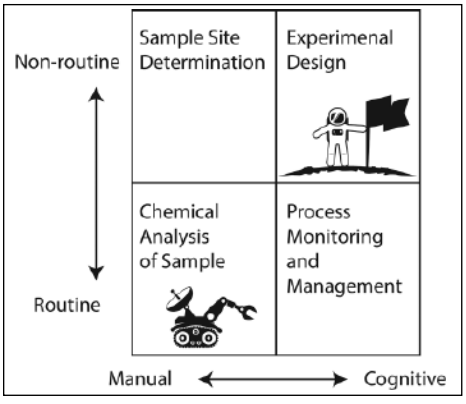
[a]Data are for persons age 25 and over. Earnings are 2015 annual averages for full-time wage and salary workers. Credit: U.S. Bureau of Labor Statistics (12 January 2017)

sales. Thus, the service of providing environmental assessments will still have a place.

Although privatization puts existing federal workers at risk, it may, in fact, be easier for job seekers to gain employment with contracting agencies than to apply through the federal hiring process. So privatization may be of benefit to new graduates looking for entry-level positions.

Most existing federal regulation jobs will likely remain, but budgets could be cut significantly. Hiring freezes may also be common in the future, to decrease the size of the government workforce through attrition. Because 25.5% of all nonseasonal full-time permanent federal employees are currently eligible for retirement (see http://bit.ly/OPMretirement), not hiring replacements for recent retirees may be one way of downsizing.

In other words, regulation watchdogs will still be present, but they won't be well fed.



Dave Harwell

Jobs fitting into the category of routine/manual can easily be done by a computer or machine, but humans still have the edge for nonroutine/cognitive jobs.

6 Automation Is Here to Stay

If a robot on Mars can do your job, you may need to worry.

Massachusetts Institute of Technology economists Daron Acemoglu and David Autor detail the kinds of jobs that are more likely to be filled by a robot or a computer algorithm than by a more expensive and more demanding human (see http://bit.ly/MIT-economists). Humans still have the edge for nonroutine jobs requiring creativity.

The key is to learn enough so that you can use technology as a tool. When you become the tool, you can easily be replaced. Don't be a tool.

Because technology continues to evolve, so should you. X-ray diffraction was once a technique requiring a skilled professional. Today a semiautonomous robot on the other side of the solar system can collect samples and analyze them remotely.

7 Opportunities Will Rise in the Gig Economy

The use of contractors, consultants, and freelancers is much more common today than it was a decade ago, and this trend is expected to continue. From the employer's perspective, contract arrangements allow for greater workforce flexibility and lower costs. Although the base salary for a contractor may be slightly higher than for a full-time employee, the overall cost to contract may be cheaper because contractors generally do not qualify for health insurance or other benefits.

If employment based on government funds is expected to go down, contractors will likely fill the void. Contractors are present in all sectors of employment, including industry, academia, and government.

For example, opportunities to work as technical writers or geological surveyors, or in any other area with easily defined deliverables, will likely increase. In academia, there has been a growing trend for the use of instructors and adjunct faculty to cover course loads. This trend will likely continue.

Holding multiple contracts may be the new modus operandi of the now and future worker. Although this is not as stable as full-time employment, it does give the worker flexibility to pursue several opportunities, gain varied experiences, keep skills fresh, and build a wide network of possible future employers.

Back to the Future

No one knows what the future has in store, but being aware of expected trends and adapting to changing conditions are your best strategies for success. As you set your goals for 2017, here are some suggestions to build your adaptability skill set:

- Learn something new every day. Keep your mind sharp and flexible.
- Be aware of your surroundings. Stay on top of changes to your field, your sector, and society; know your options and the risks to your employment and success.
- Have a plan for your success, and update it as situations change. Let the little stuff go, so that you can focus on what is most important to your success.

Change is the only constant in life. Plan on it always being there, and live your life accordingly.

By **David Harwell** (email: dharwell@agu.org; @deharwell), Assistant Director, Talent Pool, AGU

Laboratory Sharing to Improve Rock Deformation Research

College of Geosciences, Texas A&M

A visiting postdoc prepares for a high-pressure experiment in Texas A&M's John W. Handin Laboratory for Experimental Rock Deformation. The instrument pictured here is a triaxial Griggs deformation apparatus, which allows scientists to perform compression experiments at pressures and temperatures of the middle crust to upper mantle.

Imagine the scientific potential that could be unlocked if researchers with novel ideas could be matched with laboratories with cutting-edge technology. A new program promises to do that for the field of rock deformation research. In fact, such collaborations are already under way.

For example, after years of development, geoscience students at Texas A&M University are making the first direct observations of flash heating on frictional rock surfaces sliding at seismic rates using a prototype instrument at the John W. Handin Laboratory for Experimental Rock Deformation. These data are leading to a better understanding of the microphysics of friction and to an improvement of friction constitutive relations used in numerical modeling of earthquake rupture dynamics and strong ground motion.

Developing new instruments for testing the physical properties of geomaterials is key to scientific advances, and similar instrument development and learning experiences are occurring in other rock deformation laboratories throughout the world. Unfortunately, many such instruments are rarely produced beyond the prototype because of limited resources and the relatively small number of rock deformation laboratories. What's more, experimental, observational, and theoretical studies are not often integrated, as each approach requires a unique set of methods, preparation, and specialization.

> Laboratories with one-of-a-kind equipment are not available to the broader range of geoscientists. But shouldn't and couldn't they be?

How do we solve these problems? To foster new integrated research of tectonically significant processes, experimental scientists, field researchers, and modelers need shared access to working laboratories and technical support. A new group, born of discussions at meetings and workshops [*Tullis et al.,* 2013], aims to facilitate this access.

Called the Deformation Experimentation at the Frontier of Rock and Mineral research (DEFORM), the group seeks to integrate rock deformation labs across the United States into one shared national facility with access provided to visiting scientists and students.

Why Share Facilities?

Scientists who study deformation in laboratory experiments are interested in the mechanical behavior and physical properties of rocks, taking the same approach as materials scientists who investigate properties of metals and structural materials for engineering purposes. In the Earth, these properties govern tectonic responses to geodynamic loads; the rates of plate tectonics; and the catastrophic rupture, episodic slip, and creep on faults.

Experimental studies of fracture, friction, and flow of rocks provide failure and slip criteria, rate laws, and understanding of deformation fabrics, microstructures, and mechanisms that can be applied to Earth. They provide key insights into Earth's tectonics and fault zone processes on a testable scale.

For example, data collected in the lab are often used as input into numerical models of geodynamic and fault processes. Experimentally generated deformation microstructures and textures are also compared with those of naturally deformed rocks, fault gouge, cataclasites, and mylonites.

However, since the early studies of *Griggs* [1936, 1940], *Brace* [1960], and *Handin et al.* [1963], the development of rock deformation facilities in U.S. academic institutions has not kept pace with scientific needs or technical challenges faced by experimental scientists. With the exception of a few remarkable new deformation apparatuses, early prototype apparatuses have not been replaced by a new generation of advanced instruments.

With limited access to experimental facilities, feedback between experimental, theoretical, and observational approaches is restricted, and priority lab experiments are not always defined by theory or field studies. For example, numerical modelers cannot easily test predictions of their new theories of coseismic weakening of rock materials that can also creep under tectonic loading through experiments. There is little opportunity for a structural geologist to test hypotheses of the origin of frictional melting observed in a natural fault zone through laboratory experiments that isolate conditions of melt generation.

What's more, in the case of experimental studies of deformation, laboratories with one-

of-a-kind equipment, designed and built in-house, and uniquely qualified technical staff are not available to the broader range of geoscientists.

But shouldn't and couldn't they be?

Andreas Kronenberg

Graduate and undergraduate students gather in a Texas A&M laboratory to learn how friction experiments are done at sliding velocities of up to 1 meter per second. Energy dissipation at these velocities initiates dynamic weakening processes that govern earthquake rupture.

DEFORM's Vision

To address these issues, DEFORM hopes to connect individual laboratories to form a conglomerated shared facility with greater access for multidisciplinary research. Collaboration of experimental geoscientists will lead to greater access to a broad community, improved calibrations, uniform procedures, and a new generation of deformation apparatuses. Access to participating laboratories by students of theoreticians and observational scientists will lead to a new generation of interdisciplinary scientists.

The vision of DEFORM is that through this shared conglomerate, scientists will work together to enhance communication and technology exchange within the rock mechanics community, provide facilities for early-career scientists, and promote broader collaboration across geophysics, geology, and engineering.

DEFORM hopes to host schools and tutorials and directed research meetings that facilitate new collaborations, as well as instrument development workshops focused on improved designs, protocols, and experimental instrumentation. Community design efforts will involve experimental geoscientists who define the technical needs for new instrumentation and consulting professional engineers who design new apparatuses using the latest performance modeling. All of the designs generated by DEFORM will be open-source, and they may form the basis to build new apparatuses and fund major research instrumentation grants.

Table 1. Participating DEFORM Laboratories

EXPERIMENTAL CAPABILITIES[a]	LAB LOCATION
Low *P-T* facilities, crustal deformation, friction, and physical and chemical processes	Lamont-Doherty Earth Observatory Pennsylvania State University Rice University Sandia National Laboratories University of Maryland U.S. Geological Survey
Mixed facilities, low *P-T* (crustal) and high *P-T* (mantle) conditions	Brown University Texas A&M University
High *P-T* facilities, deep crust and mantle creep, attenuation	University of Akron University of California, Riverside University of Minnesota University of Nevada, Las Vegas Washington University Yale University
Cryogenic *P-T* glacier and icy satellite conditions	Lamont-Doherty Earth Observatory University of Pennsylvania

[a] *P-T* = pressure-temperature.

Building a National Facility

DEFORM is modeled, in part, after the successful research consortia Incorporated Research Institutions for Seismology (IRIS), Consortium for Materials Properties Research in Earth Sciences (COMPRES), Southern California Earthquake Center (SCEC), and University NAVSTAR Consortium (UNAVCO), which have revolutionized the fields of high-pressure mineral physics, seismology, earthquake science, and geodesy.

DEFORM already has 77 member institutions from universities and governments, including 26 international members. Most members include scientists who have applied experimental results in their own research but have no experimental facilities and welcome greater integration and feedback between experimental measurements of rock properties, geodynamics, seismology, and structural geology.

Experimental facilities consist of 15 participating rock deformation laboratories (see Table 1). These labs, plus any more that join, will form the collaborative national facility, operated by participating lab managers with oversight by DEFORM leadership. New members and experimental facilities are welcome (contact Andreas Kronenberg below).

Membership and Opportunities for Collaboration

The primary objective of DEFORM is to increase collaborative observational, theoretical, and experimental approaches to answering fundamental questions in geodynamics, seismology, earthquake source physics, geodesy, structural geology, hydrology, sedimentology, and planetary dynamics. To this end, we seek scientists who wish to undertake multidisciplinary approaches to studies such as the following:

Lithosphere dynamics and mantle flow. This approach seeks to examine, for example, mechanical properties that govern plate-like behavior of the lithosphere, the transition to flow in the asthenosphere, rates and patterns of isostatic adjustment to gla-

cial unloading and sea level change, the depth dependence of earthquakes, and seismic anisotropy associated with shear and deformation fabrics.

Earthquake physics and stability of slip on faults. Studies here include the spectrum of fault slip behaviors, mechanics of nucleation, triggering, dynamic weakening, rupture propagation, postseismic slip, aftershock decay, interseismic creep, and episodic slip.

Coupled crustal deformation and fluid flow. These studies have applications to the mechanics of accretionary prisms, coupled fault motion and fluid transport, unconventional energy and resource management, isolation of chemical and radioactive wastes, carbon dioxide sequestration, and induced seismicity.

Glacier and planetary ice dynamics. This approach scrutinizes the mechanics of glacial thinning, intraglacial meltwater transport, changes in basal boundary conditions and viscous resistance, loss of ice shelves in response to climate change, and the thermomechanical evolution and tectonics of icy satellites of the outer solar system.

A Foundation for the Future

By welcoming visiting scientists into existing rock deformation laboratories distributed across the United States, DEFORM hopes to support both young experimental geoscientists who may ultimately plan to build their own labs and the broader group of geoscientists at all career stages who want to use the shared DEFORM facilities. Opportunities go beyond collaboration: DEFORM hopes to host meetings, workshops, and summer schools for students and postdocs.

We strongly feel that access to shared laboratory facilities under the DEFORM initiative will benefit students and early-career geoscientists and help a new generation take multidisciplinary approaches in the mechanics of plate tectonics and earthquakes. Let the collaborations begin!

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USING LANDSAT TO TAKE THE LONG VIEW ON Greenland Glaciers

By Mirko Scheinert, Ralf Rosenau, and Benjamin Ebermann

Outlet glaciers, tongue-like protrusions that flow from the main body of a glacier, provide the most sensitive indication of changes occurring on the Greenland ice sheet. They exhibit a complex interplay among changes over space and time that are not yet fully understood. Many of Greenland's outlet glaciers are retreating substantially; they are flowing more rapidly and their surfaces are lowering.

Understanding the underlying driving processes requires a system that monitors an entire area on a

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Mirko Scheinert

Aerial view, looking west over Wordie glacier (74°10′ N, 23°30′ W), one of the smaller outlet glaciers in northeastern Greenland, north of Ole Rømer Land and Hudson Land. A newly released data portal enables scientists to study in unprecedented detail how fast outlet glaciers such as this one move and change over space and time.

continuous basis. Our research group has developed a new data portal that provides such an opportunity (see http://bit.ly/Landsat-portal).

This portal harnesses more than 37,000 images from Landsat archives, dating back to the early 1970s, to track changes in outlet glaciers over time. Through analyzing data from this portal, we can see in great detail how several outlet glaciers are speeding up their treks to the sea. What's more, any user can access the data to conduct their own studies of glacier behavior at Greenland's coasts through time.

Lengthening Ice Records with Landsat

Over the years, scientists have used several satellite-based techniques to monitor the Greenland ice sheet and its outlet glaciers. Satellite altimetry has provided observations of ice surface heights and height changes since the 1990s. ICESat provided higher-resolution data from 2003 to 2009, and CryoSat-2 has continued this effort since 2010.

Satellites that were used for radar altimetry also enabled researchers to infer ice flow velocities using synthetic aperture radar interferometry (InSAR) and speckle tracking. Of course, data sets from these techniques are confined to the time span during which a given satellite is collecting data.

Examining the Landsat archive, dating back to the first acquisitions of Landsat 1 in 1972, is one promising means of covering a longer time span. However, to exploit this wealth of information, scientists need a processing strategy that ensures consistent results.

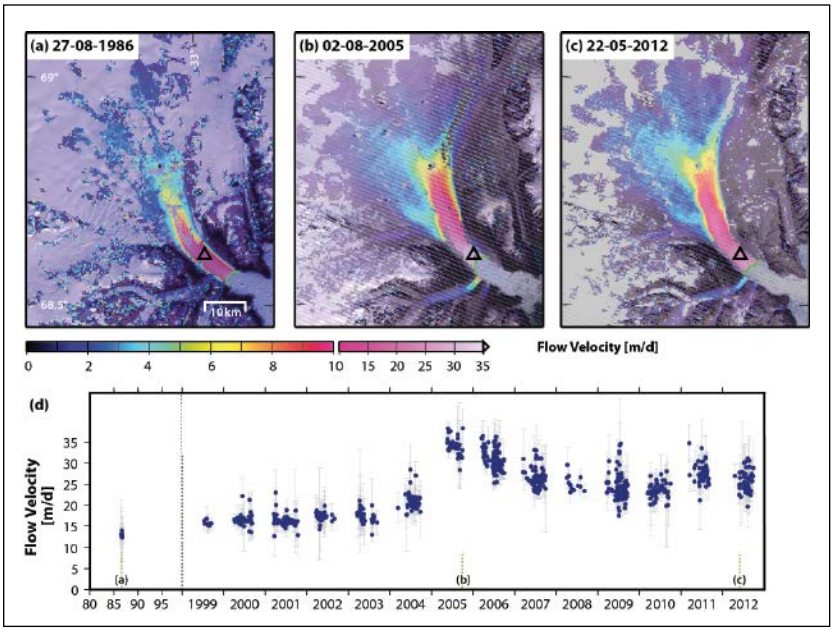
We provide that strategy. Performing some of the necessary analysis steps has only recently become possible, with the availability of improved digital elevation models and progress in computer performance and software technology. Our new interface specifically uses Landsat to track flow velocity fields of Greenland's outlet glaciers and how they have changed over time.

Thousands of Landsat Scenes Make a Greenland Database

Researchers can access our new web-based data portal to thoroughly explore how glacier flow velocities along the margin of the Greenland ice sheet have evolved over time. They can also examine seasonal variations in the flow velocity for most of Greenland's outlet glaciers, a significant new capability.

We based our project on more than 37,000 optical images collected by multiple sensors aboard the U.S. Geological Survey (USGS) and NASA Landsat satellites. The data span the period between 1972, when Landsat 1 was launched, and 2015, using data from Landsat 8 (launched in 2013), although most of the Landsat scenes were acquired after 1998.

We will continue to extend the database using new scenes recorded by the ongoing Landsat 7 and 8 missions. The USGS Landsat Global Archive Consolidation (LGAC; https://on.doi.gov/2ihOKky) will add even more scenes, providing access to Landsat data that are archived at individual international ground stations [*Wulder et al.,* 2016]. For Greenland, this could provide a considerable number of scenes from Landsat 4 and 5, dating back to 1982.



Technische Universität Dresden/Landsat (USGS)

Fig. 1. Flow velocity fields, in meters per day, of Kangerdlussuaq glacier, East Greenland, for the years (a) 1986, (b) 2005, and (c) 2012. The black triangle denotes the location from which (d) the flow velocity time series was extracted. The dotted black line marks the transition from 5-year to 1-year intervals. The dotted green lines mark mean acquisition times of the flow velocity fields in Figures 1a–1c.

These additional images are valuable for extending the time span of the velocity time series. This greater time span is particularly important for inferring flow velocity variations that occur within the span of one season, and it may help to close observation gaps that occurred before 1999, when Landsat 7 was launched. Moreover, in regions of extensive cloud coverage, collecting Landsat scenes over a longer time span increases the chance of obtaining cloud-free data.

Enhanced Data Processing Provides a Clearer Picture

For 302 glaciers all around Greenland, we have processed more than 100,000 flow velocity fields from 1972 to 2012. We have extended this processing to include velocity fields for about 50 major glaciers up to 2015 so far.

By adding a quality flag that indicates the reliability of the data, we reduced the number of existing velocity fields with extensive outliers. We used an outlier detection strategy that compared the differences between each observed velocity product and a theoretically derived velocity field to compile the statistical parameters for our evaluation. Altogether, we have made more than 40,000 flow velocity fields accessible so far, and we continue to add new velocity fields as we process more data.

Rosenau et al. [2015] described a number of steps included in the processing procedure. We have improved the correction for tilt and terrain effects (orthorectification) using the Global Digital Elevation Map Version 2 (GDEM V2) from NASA's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The improved orthorectification step, in particular, facilitates the usage of overlapping scenes from orbits that are not repeat passes. The ability to include these additional scenes provides a much higher effective sampling rate than would be provided by repeat-pass sampling, which is limited to the repeat orbit of 16 days (Landsat 4 to 8) or 18 days (Landsat 1 to 3).

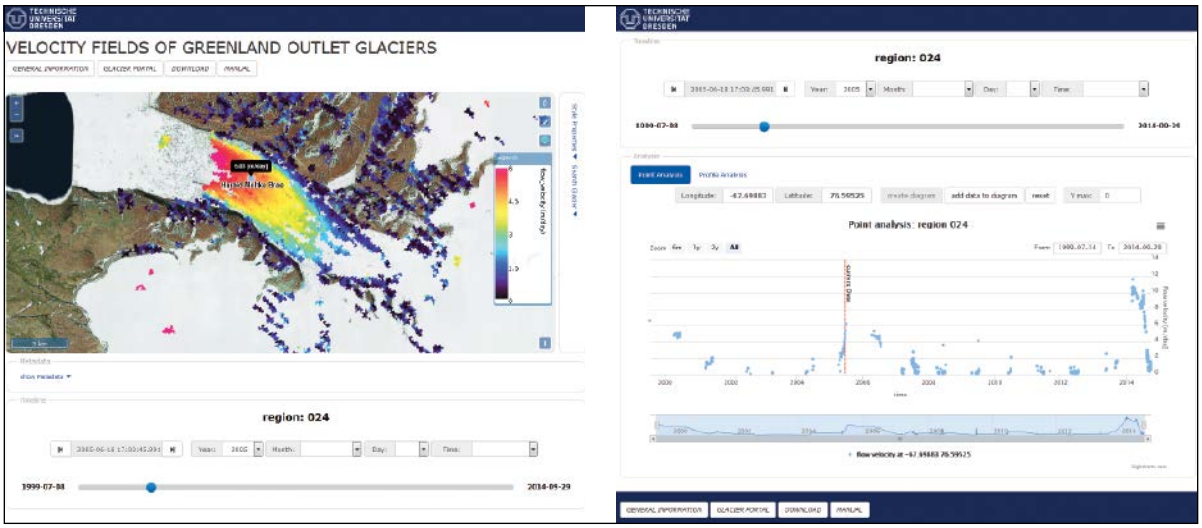
In 2003, a small pair of mirrors (the scan line corrector) aboard Landsat 7 failed, introducing data gaps as well as small shifts between the scan lines. We applied a destriping correction to mitigate the impact on the resulting velocity fields. In addition, we removed outliers using an adaptive, recursive filter approach. The combination of all these improvements leads to higher accuracy of the inferred velocity fields.

Long-Term and Seasonal Trends in Flow Velocity

The long time span covered by the Landsat scenes allows us to determine long-term flow velocity trends. The high temporal resolution lets us analyze seasonal flow velocity variations of numerous outlet glaciers. However, the pattern of temporal and spatial distributions of the flow velocity changes is not uniform (Figure 1). The monitoring system provides a powerful tool to examine the flow velocity pattern throughout time and space, and we have detected an acceleration pattern for a number of outlet glaciers.

Performing some of the necessary analysis steps has only recently become possible.

These findings are consistent with most previously published results [e.g., *Moon et al.,* 2014], and rapid changes can now be analyzed in detail. For example, in addition to the known 2005 surge of Harald Moltke Bræ (an outlet glacier in northwestern Greenland), we found



Technische Universität Dresden/Landsat (USGS)

Fig. 2. (left) Screenshot of map selection frame in the web portal display. This example shows region 24, which includes the Harald Moltke Bræ outlet glacier. Several functionalities, including style and legend properties, are accessible on the right-hand side of the screen. A user can choose a specific time in different ways using the timeline frame below the map selection frame. (right) Screenshot of the point analysis tool section of the web portal display. Users can freely select a specific point in the map frame, for which they can retrieve the flow velocity time series. The time series for further locations can be added to the same diagram. In this section of the display, the analysis can be switched to analyze profiles that are also freely selectable in the map frame.

further periods of similarly high flow velocities during 1999–2000 (Figure 2).

The nonuniform, high variability of the flow velocity pattern along the margin of the Greenland ice sheet is especially evident in northeastern Greenland (Figure 3). For example, analysis of data spanning the past decade revealed no significant change in the flow velocity for the outlet glacier Nioghalvfjerdsbræ close to the grounding line.

In contrast, Zachariae Isstrøm, its neighbor to the south, features a flow velocity acceleration of 43%. This acceleration is correlated with the breakup of the glacier's floating part that formerly formed an ice shelf between Lambert Land, which divides Zachariae Isstrøm from Nioghalvfjerdsbræ, and the off-coast island of Schnauder Ø. *Rosenau et al.* [2015] have discussed the resulting flow velocity fields and their changes in greater detail.

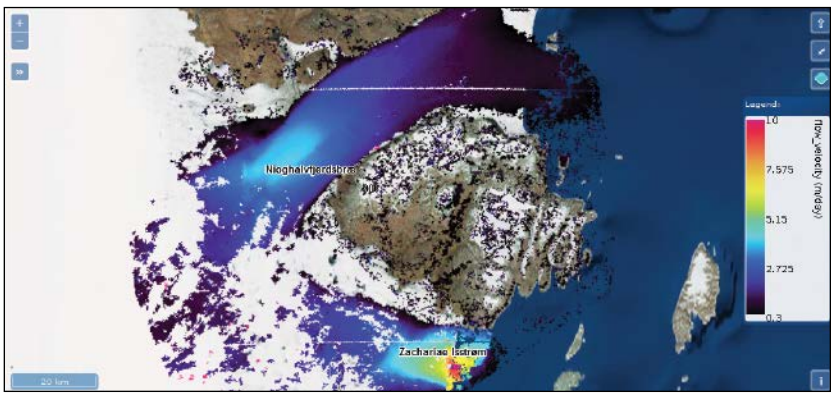


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Fig. 3. Flow velocity field inferred for the outlet glaciers of the Northeast Greenland Ice Stream, Nioghalvfjerdsbræ and Zachariae Isstrøm, as of 12 May 2013.

Web Portal Lets Scientists Apply the Data

We built the new data portal as a publicly accessible web interface to the database, which was accomplished in close cooperation with our colleagues of Technische Universität Dresden's Professorship of Geoinformatics. The portal facilitates web-based calculations to derive information such as flow velocities along profiles or time series for a glacier location that can be interactively selected on the map. The portal offers various data download options. For the time being, the data portal is focused on the specific project for the Greenland outlet glaciers. However, the techniques and methods used in the data portal offer great flexibility and general usability.

The data are stored in the well-established Network Common Data Form (NetCDF) format. For handling and processing the huge number of Landsat scenes, we created a relational database using PostgreSQL. Thematic Real-time Environmental Distributed Data Services (THREDDS) provides an interface between data, metadata, scientific calculations, and map services. The Web Map Service (WMS), which is integrated into THREDDS, displays the results.

This interface also allows users to apply specific analysis tools. The point analysis, for example, incorporates the standardized function "GetFeatureInfo." With such built-in techniques, THREDDS lets us retrieve the velocity at a given point for all velocity fields within one NetCDF file, yielding a time series at the specific location (Figure 2).

These calculations are performed on demand; that is, any calculation is made at the time

Mirko Scheinert

Aerial view, looking north over the front of Nioghalvfjerdsbræ (79°30′ N, 19°30′ W). Nioghalvfjerdsbræ and its southern neighbor, Zachariae Isstrøm, form the major outlet glaciers of the Northeast Greenland Ice Stream.

the user requests it. The host server completes all calculations and interface processes in the background, and the resulting maps and graphics are then displayed on the user's screen.

We also incorporated a submenu "manual" that provides assistance on how to handle the data portal and the analysis tools it offers. Given this flexibility, the web-based techniques could be applied to include other sensors and to extend the processing to other regions featuring similar ice flow behavior, the margin of the Antarctic ice sheet, for example.

A New View of Greenland's Glaciers

State-of-the-art web-based techniques enable us to provide the scientific user with a powerful data portal to explore the temporal evolution of the glacier flow velocity of more than 300 Greenland outlet glaciers. The portal allows users to rapidly determine seasonal variations of the flow velocity, calculations that only data from this portal can accomplish.

USGS is distributing newly acquired Landsat scenes in near-real time, which enables us to process these scenes immediately and rapidly integrate the inferred flow velocity products into the web portal. This will allow researchers to quickly access and analyze the velocity information, especially in regions where the dynamics of the outlet glaciers change rapidly.

The ability to analyze changes in glaciers as they are happening, coupled with the context provided by decades of satellite data, provides scientists with an unprecedented ability to gain understanding of the processes that drive the rapid changes in high-latitude glaciers. With this information, they can better evaluate the consequences of those changes.

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Transforming Satellite Data into WEATHER FORECASTS

By Emily Berndt, Andrew Molthan, William W. Vaughan, and Kevin Fuell

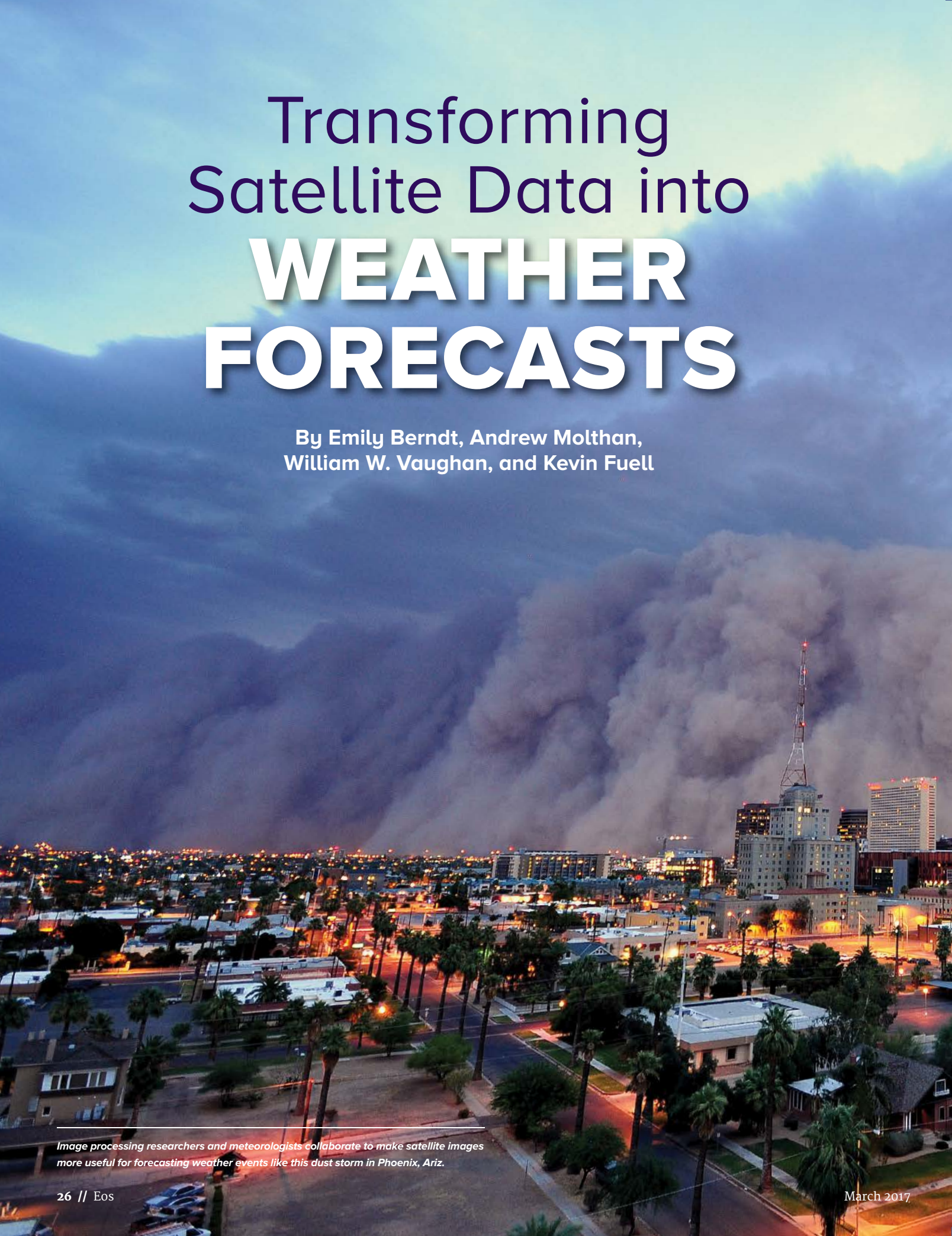

Image processing researchers and meteorologists collaborate to make satellite images more useful for forecasting weather events like this dust storm in Phoenix, Ariz.

Satellite imagery has been of immense benefit to weather forecasters. With it, they can assess aviation hazards such as low clouds, monitor thunderstorms, and track the evolution of dust plumes.

Satellite sensors are continually evolving to provide ever greater imaging capabilities, and researchers continue to develop advanced techniques to identify hazards in satellite imagery. However, barriers can prevent experimental products from reaching forecasters in the operational environment.

A NASA project has developed an interactive process whereby weather forecasters learn to interpret the latest satellite imagery and apply it to their operations. Forecasters then provide feedback to the researchers who are developing algorithms and products to further improve future products. This effort has taken on greater importance with the anticipated launch of a new series of satellites that will provide substantially greater amounts of data than are currently available.

Visualizing a Wealth of Data

Multispectral composites combine satellite data collected at different wavelengths of the electromagnetic spectrum and present them as red-green-blue (RGB) images, which serve as enhanced representations of specific phenomena such as low clouds and fog. With the launch of the Geostationary Operational Environmental Satellite–R Series (GOES-R, now called GOES-16) on 19 November 2016 and the first of the Joint Polar Satellite System (JPSS) series in 2017, U.S. National Weather Service (NWS) forecasters will have access to a wider array of imagery than is available with the current GOES satellites.

The current GOES satellites collect data from only five ranges of wavelengths in the electromag-

Daniel J Bryant/Getty Images

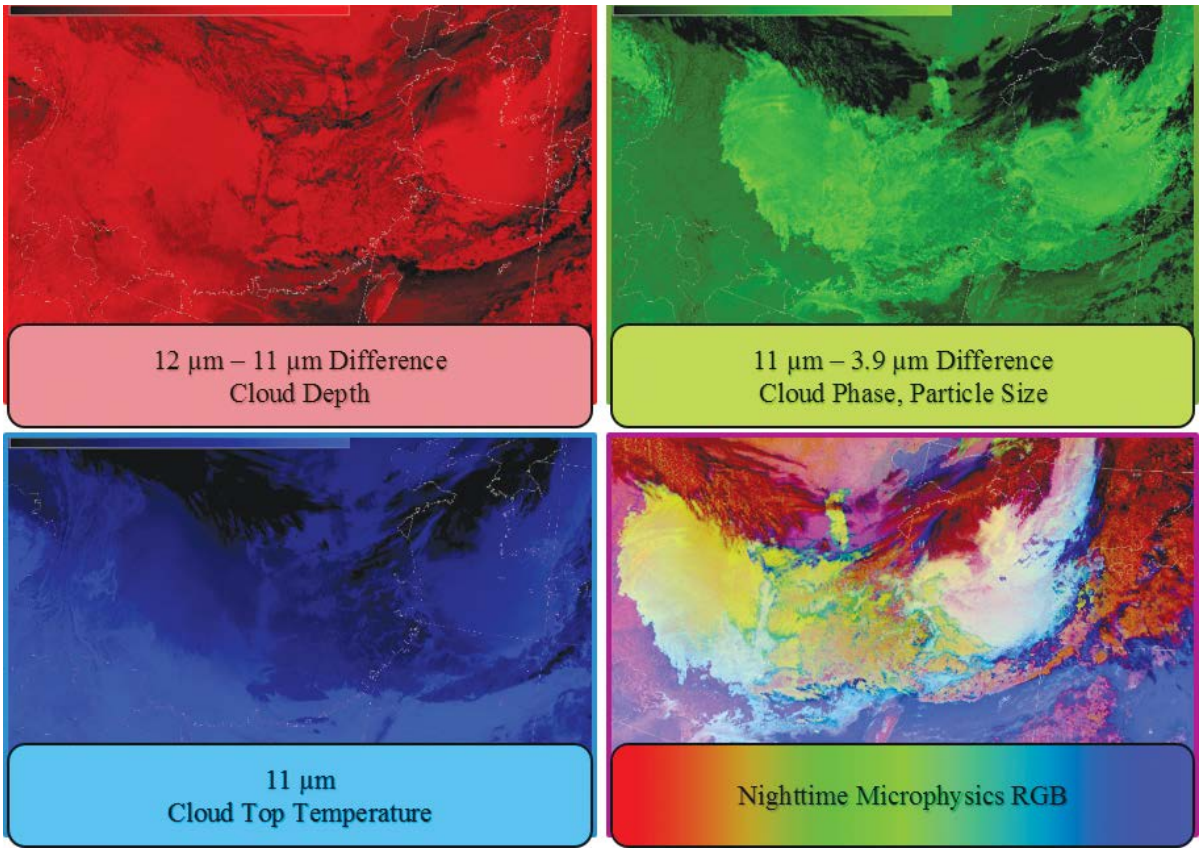

Fig. 1. Red, green, and blue components for the Nighttime Microphysics (NtMicro) RGB imagery and the resulting composite image. Imagery was derived from the Himawari-8 satellite using channels similar to those that will be available on GOES-16.

netic spectrum, called bands. GOES-16 will have a total of 16 bands. The increased number of bands, and the resulting increase in the data richness of imagery, creates an even greater need for RGB images, which provide the ability to synthesize information from several bands into a single image for rapid interpretation.

The NASA Short-term Prediction Research and Transition Center (SPoRT; http://go.nasa.gov/2j5GgKF) has used a research-to-operations/operations-to-research (R2O/O2R) paradigm to introduce RGB imagery to NWS forecasters to prepare them for new capabilities that will be available in the future.

Application and Feedback

Keys to this paradigm are active collaboration with end users (the weather forecasters), distribution of experimental products for use in end user display systems, creation of applications-based training materials, and evaluation of experimental products to gather end user feedback. SPoRT has applied its R2O/O2R paradigm to support the introduction of RGB imagery to NWS forecast offices since the early 2000s, when SPoRT worked with partner NWS forecast offices to introduce Moderate Resolution Imaging Spectroradiometer (MODIS) true-color and false-color RGB imagery to forecasters.

As a result of close collaboration with partner NWS forecast offices, weather forecasters now routinely use various types of RGB imagery in their operations. For example, the Nighttime Microphysics (NtMicro) RGB is widely used to differentiate between fog and low clouds, which is useful for assessing aviation hazards. The Dust RGB, which monitors the evolution of dust plumes, has been adopted into daily operations at the Albuquerque, N.M., NWS forecast office [*Fuell et al.,* 2016]. Forecasters at the NWS Ocean Prediction Center routinely use the Air Mass RGB, which highlights differences between tropical and polar air masses, to assist with forecasting strong midlatitude cyclones [*Zavodsky et al.,* 2013; *Berndt et al.,* 2016].

Over the past 7 years, SPoRT has played an integral role in introducing RGB imagery and applications-based training to NWS forecasters. These efforts also serve to develop innovative solutions to display imagery in the operational environment to prepare forecasters for advanced imagery available with next-generation satellites.

History and Best Practices

In 2002, the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) led an effort to develop RGB products from the data collected by newly launched satellites. The effort produced a set of best practices that included recipes for a suite of standard RGB products [*Lensky and Rosenfeld,* 2008; *EUMETSAT,* 2009]. The World Meteorological Organization later adopted these RGB best practices to develop a set of standard products among international partners.

Best practices ensure that RGB products are developed with a defined recipe and that each product is well adapted to its intended use so that forecasters know what they are looking at in a given RGB product. Because RGB images are designed to enhance a specific phenomenon, individual spectral bands or differences between pairs of bands are chosen for an RGB image on the basis of the use of specific satellite bands to detect particular features.

For example, the NtMicro RGB was designed to enhance low-cloud and fog features. This RGB recipe (Figure 1) incorporates the well-known brightness temperature difference (ΔBT) between 11 micrometers (μm) and 3.9 μm. This quantity represents the difference in the intensity of the long- and short-wave infrared radiation at these two wavelengths that travels upward from the atmosphere to the satellite, and it is traditionally used to differentiate between water and ice clouds. The 12- and 11-μm ΔBT helps to distinguish between high, thick clouds and high, thin clouds by delineating cloud phase (ice or liquid water) and cloud particle size (small or large). The 11-μm brightness temperature is included to enhance low, warm clouds and distinguish them from colder, higher clouds.

Once the purpose for the RGB image (e.g., monitoring low clouds and fog) and the bands and/or band differences are chosen, the images are preprocessed to improve contrast and sharpen features of interest. The images are then assigned to the red, green, and blue components to create a single RGB image, as depicted in Figure 1.

From 2009 to 2011, SPoRT focused its efforts on developing a technique to display EUMETSAT RGB products derived from polar-orbiting satellites in NWS display systems. They also developed training materials and introduced the RGB imagery to NWS forecasters.

Because the current generation of GOES does not have enough bands to create the EUMETSAT RGB products, imagery from research instruments was used to introduce NWS forecasters to the new imagery that would be routinely available in the future with GOES-16. For example, by 2012, SPoRT was using data from MODIS and the Visible Infrared Imaging Radiometer Suite (VIIRS) to mock up the RGBs that could be created with GOES-16 bands.

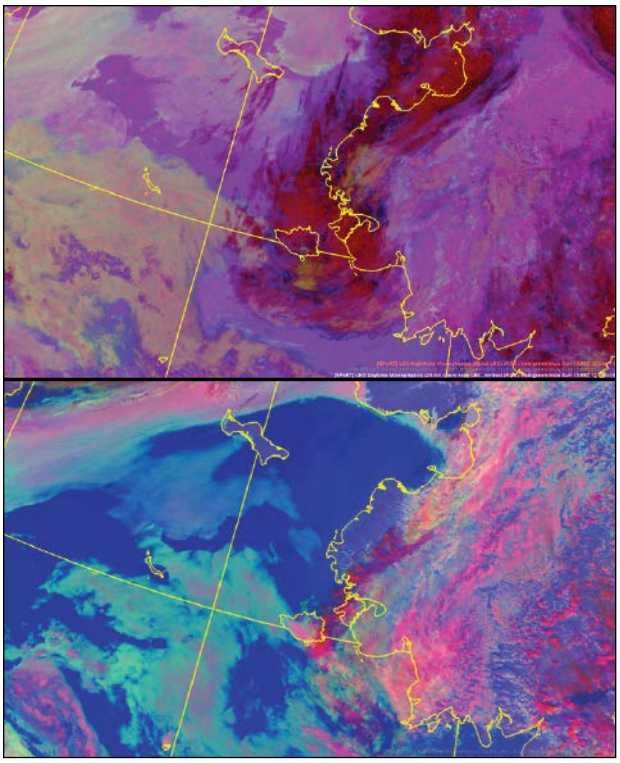

Fig. 2. VIIRS data display for (top) nighttime and (bottom) daytime low clouds and fog over the Bering Sea, using NtMicro and DtMicro RGB composite images, respectively. NASA SPoRT processed satellite imagery for 12 June 2016 at 12:59 coordinated universal time. Low-cloud and fog features are dull aqua and gray in the NtMicro images and aqua in the DtMicro images.

Interaction with the End Users

Today, partner NWS forecast offices across the United States use the NtMicro RGB most widely. The Alaska region especially benefits from this satellite imagery. In Alaska's vast expanse of remote, complex terrain, low clouds and fog are a frequent hazard. The NtMicro RGB has become a part of daily operations in the Alaska NWS forecast offices as a result of an interactive partnership in which SPoRT conducted targeted product assessments of a variety of RGB products with forecasters.

Alaska NWS forecast offices participated in an assessment during the 2013–2014 winter, and SPoRT obtained feedback about the use of RGB from individual forecasters with a short online survey. The survey results indicated that the NtMicro RGB was valuable for distinguishing fog from low clouds beyond the traditional 11- and 3.9-μm ΔBT and that use of the RGB products gave them more confidence when issuing aviation forecasts [*SPoRT,* 2014].

With the extreme range in hours of day and night unique to the high latitudes, the NtMicro RGB is most useful during periods of extended nighttime during the Alaskan winter. Therefore, forecasters inquired about a similar product for use during the summer. SPoRT recently developed the capability to derive the EUMETSAT daytime microphysics (DtMicro) RGB [*Rosenfeld and Lensky,* 1998; *Lensky and Rosenfeld,* 2008; *EUMETSAT,* 2009].

The DtMicro RGB is specifically designed to complement the NtMicro RGB for tracking low clouds and fog during the day (Figure 2). Alaska region partners assessed the utility of the DtMicro RGB during the 2016 summer, and they provided feedback that the imagery had a positive impact on operations and influenced aviation forecasts similarly to the NtMicro RGB. In addition, forecasters found the DtMicro RGB valuable for identifying strong thunderstorms and low-level rain clouds.

This example of the success of the SPoRT R2O/O2R paradigm involves the EUMETSAT microphysics RGB products and the Alaska region partners. Additional NWS partners across the United States are interacting with SPoRT to integrate RGB imagery into operations and prepare for the wealth of new imagery available with GOES-16 in the near future.

The Future of Multispectral Imagery

SPoRT continues to apply its successful research-to-operations paradigm to prepare forecasters for the capabilities that will be available from next-generation satellites. Forecasters soon will have access to all 16 spectral bands

observed by the new GOES-16 satellite via their display system, known as the Advanced Weather Interactive Processing System (AWIPS; http://bit.ly/AWIPS-support). SPoRT worked with a team of AWIPS programmers to develop the capability to generate RGB products directly within the AWIPS workstation, which provides greater flexibility in product generation and improved color quality.

In addition, SPoRT developed a plug-in for AWIPS that allows forecasters to review quick-reference material. This is ideal for accessing short refresher training for moments when a forecaster needs to quickly look up information about a product. This new capability allows forecasters to view reference material and real-time imagery at the same time to reinforce concepts without interrupting workflow.

The NWS Operations Proving Ground evaluated these new innovative capabilities during March and April of 2016. In particular, forecasters were excited about the possibility of accessing training material directly in AWIPS.

SPoRT continues to lead the community in providing multispectral composites to NWS partners through interactive partnerships, innovative training approaches, and targeted assessments tailored to specific forecasting challenges. More information and updates on this project are available on the blog *The Wide World of SPoRT* (https://nasasport.wordpress.com), the NASA SPoRT Center Facebook page (http://bit.ly/NASA-Sport-FB), and Twitter at @NASA_SPoRT.

Acknowledgments

SPoRT works in close collaboration with the GOES-R and JPSS Proving Grounds, National Oceanic and Atmospheric Administration (NOAA) NWS Operations Proving Ground, and NOAA Cooperative Institutes.

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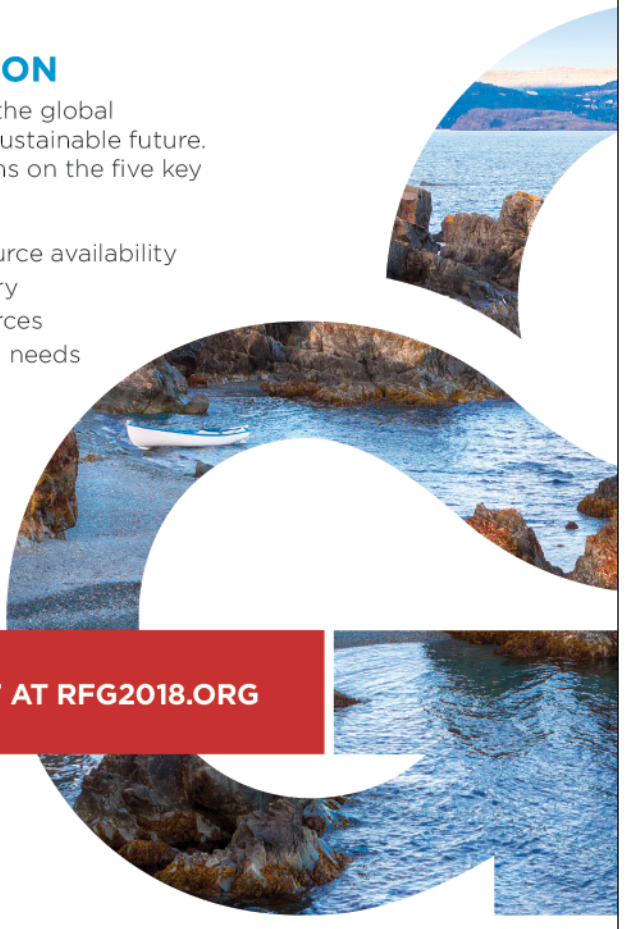

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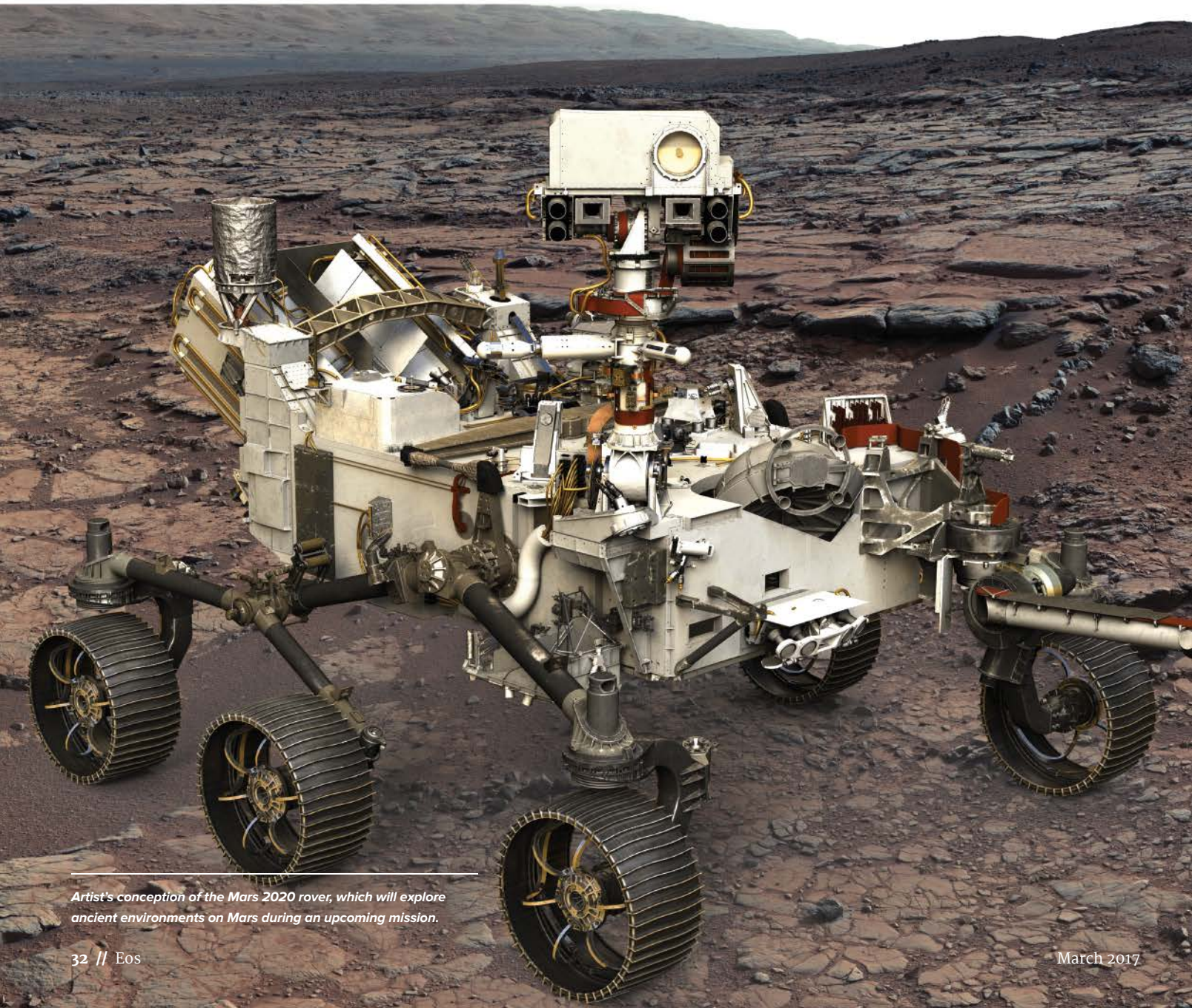
Seeking Signs

NASA's Mars

By K. A. Farley and K. H. Williford



Artist's conception of the Mars 2020 rover, which will explore ancient environments on Mars during an upcoming mission.

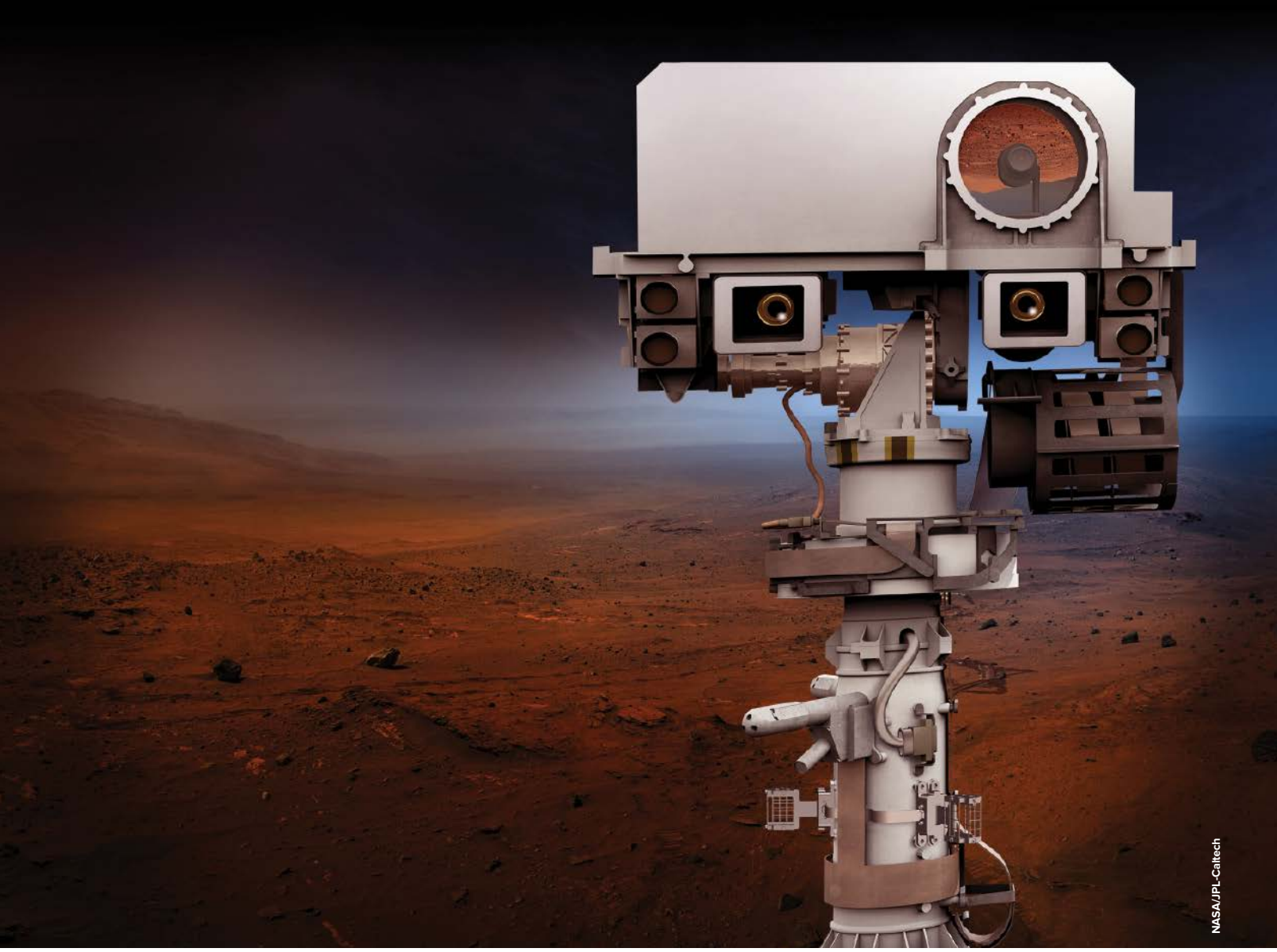
# of Life and More:

2020 Mission

Rover: NASA/JPL-Caltech; background image: NASA/JPL-Caltech/MSSS

NASA recently confirmed that it plans to fly to Mars in 2020, sending the fifth in a series of increasingly ambitious rovers to investigate the Red Planet. The specific landing site hasn't been chosen yet, but the Mars 2020 mission will explore one of several possible paleoenvironments older than 3.5 billion years that might once have been conducive to microbial life.

The rover will assess the geology of the landing site and analyze surface targets for signs of ancient life using imaging, organic and inorganic geochemistry, and mineralogy. Notably, the rover, also called



Artist's conception of the instrument mast for NASA's Mars 2020 rover, which will carry out new objectives using the basic engineering of NASA's Mars Science Laboratory/Curiosity.

Mars 2020 (see http://go.nasa.gov/2iMOKW8), will be the first to select, collect, and cache a suite of samples from another planet for possible future return to Earth, fulfilling the vision of the most recent planetary science decadal survey to take the first step toward Mars Sample Return [*National Research Council,* 2011].

A Shift in Strategy

Previous rovers used sophisticated analytic instruments and prepared rock and soil specimens for analysis on board the rover itself. Mars 2020, however, will be the first rover tasked with detailed exploration of the surface to support the collection of a large, high-value sample suite designated for possible later study in laboratories back on Earth.

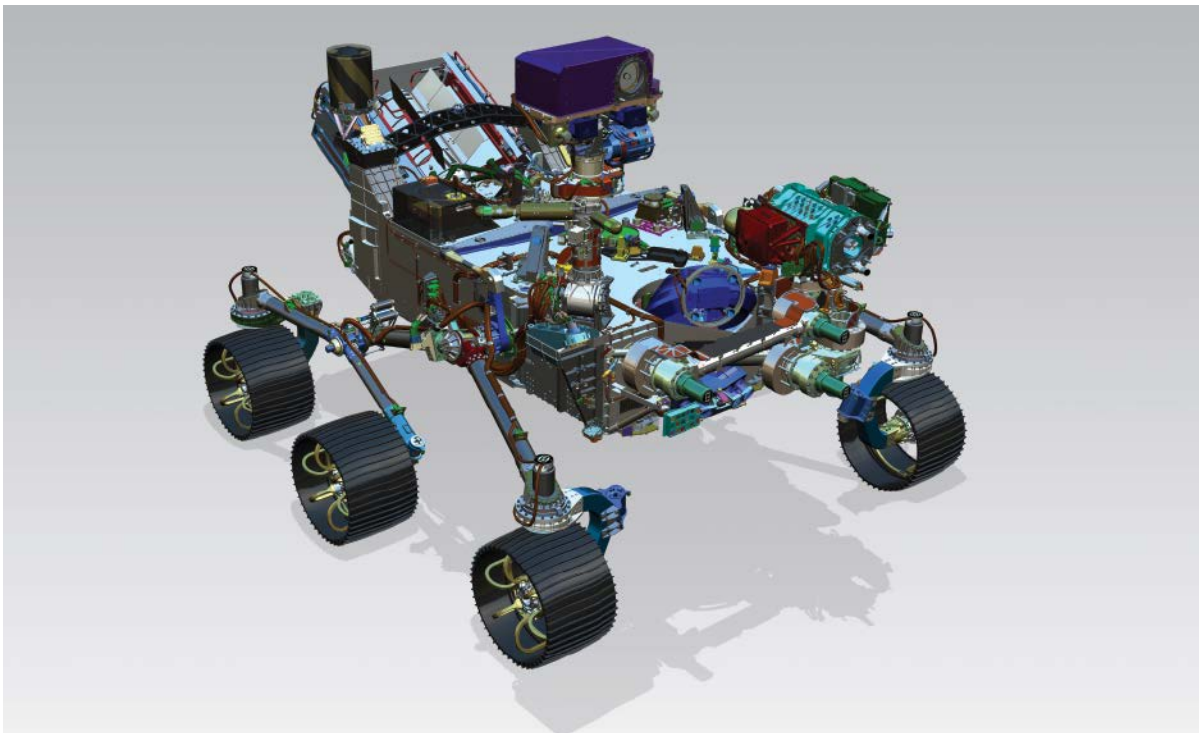
Conceptually, Mars 2020 marks a transition from missions in which sampling guided exploration to one in which exploration guides sampling. In other words, the rover's scientific instruments will observe the surrounding terrain and provide the critical context for choosing where samples will be collected. Ultimately, this context will also be used to interpret the samples. This evolution is familiar on Earth, where initial field observations and limited sampling in the service of geologic mapping lead to hypotheses that are eventually tested through focused sample collection and laboratory analysis.

Instruments on Board

The architecture of this mission closely follows the highly successful Mars Science Laboratory (MSL) and its Curiosity rover, but Mars 2020 will be modified with new scientific instruments and capabilities that allow more intensive and efficient use of the rover (Figure 1).

Two instruments will be mounted on the rover mast: Mastcam-Z, a high-resolution, color stereo zoom camera, and SuperCam, a multifaceted instrument that collects spectroscopic data using visible–near-infrared (Vis-NIR), Raman, and laser-induced breakdown spectroscopy (LIBS) techniques. SuperCam will analyze data from rock and regolith materials that may be several meters away from the rover to characterize their texture, mineralogy, and chemistry.

Two instruments on the robotic arm will permit researchers to study rock surfaces with unprecedented spatial resolution (features as small as about 100 micrometers). The Planetary Instrument for X-ray Lithochemistry (PIXL) will use X-ray fluorescence to map elemental composition, whereas Scanning Habit-



NASA/JPL-Caltech

Fig. 1. The Mars 2020 rover closely follows the design of Curiosity, but it has new scientific instruments and a sampling and caching system for the drilling and storage of samples for possible return to Earth.

able Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) will use deep-UV Raman and fluorescence spectroscopy to map the molecular chemistry of organic matter and select mineral classes. SHERLOC also includes a high-resolution color microscopic imager.

The rover will be able to assess subsurface geologic structure using a ground-penetrating radar instrument called Radar Imager for Mars' Subsurface Experiment (RIMFAX). The rover will characterize environmental conditions, including temperature, humidity, and winds, using the Mars Environmental Dynamics Analyzer (MEDA) instrument. The Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) will demonstrate a critical technology for human exploration of Mars by converting carbon dioxide in the atmosphere to oxygen as a potential source of rocket propellant.

Table 1. Requirements for the Samples to Be Prepared for Caching by the Mars 2020 Mission

CATEGORY	REQUIREMENT
Number of samples	at least 31
Sample mass, each	10- to 15-gram cylindrical cores
Contamination limits	
Inorganic	limits on 21 key geochemical elements based on Martian meteorite concentrations
Organic	<10 parts per billion total organic carbon <1 part per billion of 10 critical marker compounds
Biologic	less than one viable Earth organism per sample
Drilling and storage temperature	<60°C at all times, including during depot on Mars surface
Individual sample tube sealing	hermetic (to prevent volatile loss as well as contamination)
Sample disaggregation	maintain large pieces during drilling, storage, and possible Earth return to retain petrologic context

Rover Hits the Ground Running

In addition to the new scientific instruments, Mars 2020 builds on the innovative MSL "sky crane" entry, descent, and landing system. The sky crane lowers the rover to the surface from a rocket-powered descent stage rather than using air bags to provide a soft landing. New onboard navigational capabilities will enable the rover to land closer to regions with abundant rock outcroppings, which are scientifically desirable but potentially hazardous for landing. The rover will also have stronger wheels to reduce the puncture problems that plague the Curiosity rover.

New onboard software provides the rover with more autonomy for driving and for science investigations. New Earth-based tools and practices will enable the operations team to assess results and develop the next planning cycle over a much shorter timeline.

Studying the Samples

Mars 2020 will carry an entirely new subsystem to collect and prepare samples. As studies of lunar samples returned by the Apollo missions demonstrated, specimens brought back from Mars would be analyzed for an extraordinary

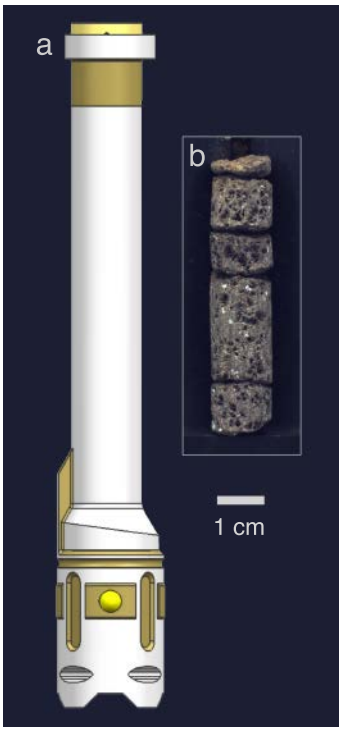


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Fig. 2. (a) Illustration of a sample tube. Sample tubes will be coated with titanium nitride (gold color) to limit organic molecule adsorption and with aluminum oxide (white) to reduce solar heating while the tubes are on Mars's surface. The tube is mounted within a rotary-percussive drill bit, and sample core material is introduced directly into the tube through an opening (located at the top in the orientation shown here). Features at the bottom of the tube are used for robotic tube manipulation. (b) Samples are cylindrical cores, typically 7.5 centimeters in length. Samples frequently break into fragments during drilling, as illustrated by this terrestrial basalt test core. Both images are at the scale indicated.

diversity of purposes. Notable examples include igneous and sedimentary petrology, geochemistry, geochronology, and astrobiology.

Samples brought back to Earth would also help researchers assess hazards associated with possible human exploration of Mars. And, of course, the samples would be analyzed for the presence of current life on Mars.

Readying samples for such study creates demanding requirements on this subsystem (Table 1). These requirements and their implementation are informed by previous studies [e.g., *McLennan et al.,* 2012; *Summons et al.,* 2014], as well as by the mission's Returned Sample Science Board (see http://bit.ly/Mars-returned-samples). Notable among these requirements are capabilities to ensure that contamination from Earth, brought over by the spacecraft, is limited to less than 10 parts per billion of total organic carbon and statistically less than one viable Earth organism in each of the returned samples.

Coring, Sealing, and Storing

The rover will carry a rack of about 40 sample tubes, each capable of holding a single core of rock or regolith measuring about 7.5 cubic centimeters and weighing about 10–15 grams (Figure 2). To collect a sample, the rover will withdraw a clean tube from the tube silo and insert it into a reusable coring drill bit. This assembly will then be inserted into the drill mechanism on the robotic arm and placed on the target.

The drill bit will use rotary motion with or without percussion to penetrate the rock and to force the core into the sample tube. After the core is broken off from the surrounding rock, the drill bit will be returned to storage. The sample and tube will be handed off to an assembly that carries the tubes through a series of stations: The sample will be photographed, the sample volume will be confirmed, and a cap will be inserted that provides a hermetic metal-on-metal seal that prevents contamination and loss of volatile components.

As a quality assurance check, the rover will carry and process multiple blank sample tubes. If the sample tubes pick up any Earth-sourced elemental, organic, or biologic contamination during the mission and possible Earth return, the blank samples will indicate the presence and nature of this contamination.

Mars 2020 has adopted an approach to caching in which sample tubes are filled and stored on board the rover. When the rover obtains an adequate number of samples, it will deposit them as a cache in a "depot" on the Martian surface for possible return to Earth.

The depot's location will be carefully selected to prevent blowing sand and dust from obscuring the individual tubes. A vehicle from a possible follow-on element of the Mars Sample Return campaign could easily locate and pick up the samples. The tubes are designed to survive for at least a decade after being deposited on the surface and another decade in space on the potential return journey.

Making Preparations

Mars 2020 is currently under development at the Jet Propulsion Laboratory in Pasadena, Calif. The mission has a 2-month launch window in midsummer 2020, followed by landing in February 2021. Mars 2020 has a prime mission of at least 1 Mars year (just under 2 Earth years).

Eight potential landing sites are now being considered. Scientists have hypothesized that environments at these sites range from ancient rivers, lakes, and deltas to extensive hydrothermal systems, similar to hot springs found on Earth.

Over the next few years, the landing site list will be honed down to a single site and a backup site that meet scientific desires and engineering constraints. The most recent Mars 2020 landing site workshop (see http://go.nasa.gov/2ilOgVL) was held 8–10 February 2017. We highly encourage the continued involvement of the broad scientific community, including scientists who may someday analyze the returned samples, in site selection.

Acknowledgment

This project is being developed at the Jet Propulsion Laboratory, California Institute of Technology, for NASA.

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AGU Approves Renovation of Headquarters

(Left) Kevin Koski, Courtesy of AGU; (right) Hickok Cole Architects

(Left) AGU's current headquarters, built in 1994, which is due for renovation this spring. (right) An artist's rendering of the updated building, which will sport an array of rooftop solar panels and other features to achieve net zero energy consumption.

On 10 December 2016, AGU's Board of Directors officially approved the $41.7 million renovation of the organization's headquarters in the Dupont Circle neighborhood of Washington, D. C. The existing building will be updated to feature a collaborative, state-of-the-art space for AGU members, AGU staff, and the public and will build understanding of Earth and space science and showcase advancement through innovative sustainable technology. As this magazine went to press, construction was set to begin in early March.

The renovation proposal underwent an 18-month approval process that involved securing zoning exemptions from the Board of Zoning Adjustment and winning support from the Historic Preservation Review Board and Advisory Neighborhood Commission 2B. The updated design will further AGU's vision of communicating science and its benefits to society, encouraging collaboration, and promoting sustainability.

The updated design will further AGU's vision of communicating science and its benefits to society, encouraging collaboration, and promoting sustainability.

A Neighborhood Landmark

The 22-year-old building has an established legacy in the neighborhood, which the renovated building will preserve and expand. To further community involvement, the renovated building will host exhibits open to the public. The scientific disciplines that AGU members and their fellow Earth and space scientists study—such as air quality, rainfall trends, and climate change—directly affect people in the Dupont Circle community and around the world. The exhibits will showcase member work, sharing the positive effects of Earth and space science and demonstrating humanity's relationship to the universe.

A Dynamic Workspace for Staff and Members

The renovated building will feature a state-of-the-art conference space for AGU and outside groups, as well as areas where visiting members can meet, present, and discuss in small or informal groups. Members and staff will benefit from the renovated building's dynamic, collaborative environments. The building itself is designed to reflect the disciplines that AGU members study, and public exhibits will elevate the visibility of member achievements.

A Sustainable Future

The new building will have an impact beyond Dupont Circle and even beyond AGU's member community. This will be the first renovated commercial building in Washington, D. C., to achieve net zero energy consumption, that is, to produce on site the same amount of energy that it uses over the course of the year. To help accomplish this, the plans incorporate a variety of sustainable technologies, including an array of about 660 four-by-eight-foot solar panels, a water reclamation cistern, and a municipal sewer heat exchange system.

Further, the renovation project will repurpose and recycle the existing architecture and its iconic materials. AGU hopes that the project will become a model for other commercial renovation and construction as the District reduces its environmental impact.

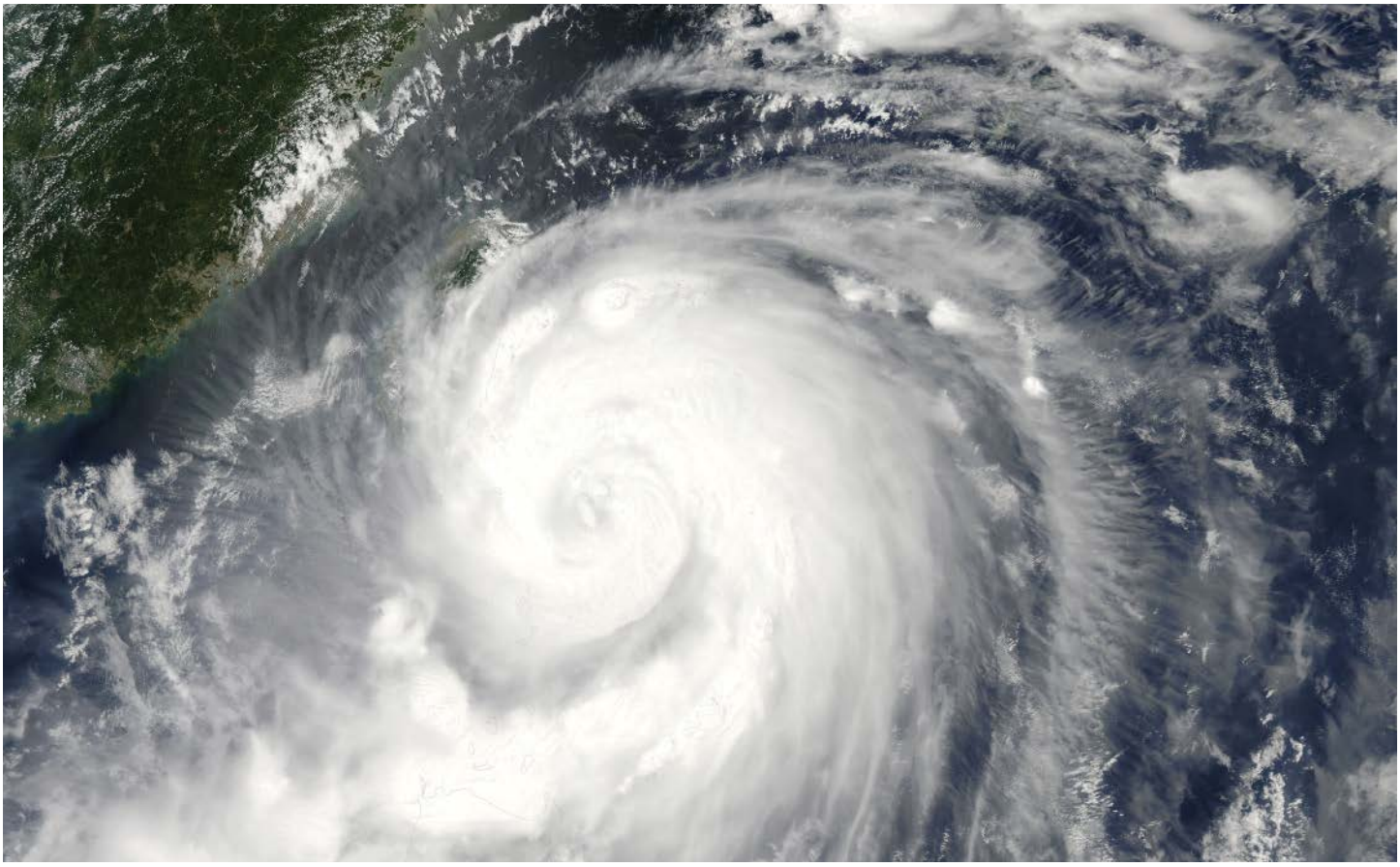
Moving Forward

During the renovation, AGU operations will continue as usual from a temporary space in downtown Washington, to which AGU staff relocated in February. Construction is expected to wrap up in time for the 10–14 December 2018 "Welcome Home" kickoff that will launch the 51st annual Fall Meeting, to be held in Washington, D. C., and AGU's 2019 centennial.

Follow the building's progress and learn more at http://bit.ly/AGUbldg.

By **Elizabeth Jacobsen,** Staff Writer

Reading Raindrops: Microphysics in Typhoon Matmo



NASA

Typhoon Matmo, pictured here approaching Taiwan in July 2014, demonstrated microphysical processes different from those of other apparently similar tropical storms, including an abundance of small raindrops.

When tropical cyclones pass over land, they can be disastrous to coastal areas. Scientists can paint a fairly accurate picture of cyclones' trajectories and intensities, but their ability to quantitatively predict the heavy rainfall that accompanies these storms is less advanced. The quantitative forecasts require a more precise understanding of the physics of tropical cyclones, down to the size of a single raindrop.

In a new study, *Wang et al.* used relatively new observational methods to examine microphysical processes in a typhoon's rainband, the line of heavy showers—generated by temperature differences—that spirals in toward the storm's center and gives a hurricane its distinctive whorl shape.

Typhoon Matmo made landfall in Fuqing, Fujian Province, China, in July 2014. As it moved inland, the storm passed over an intensive observation area of the Observation, Prediction, and Analysis of Severe Convection of China (OPACC) project, where the microphysical and kinematic structures of its rainband were captured by OPACC's instruments. The data provided the researchers with insights into the size distribution of raindrops and allowed them to make inferences about the movement of air and water through the storm.

The team found that, generally, the rainband of Typhoon Matmo contained lots of small drops (with radii under 1 millimeter) and only a few larger ones. As the storm progressed, the drops increased in size and the rainfall intensified; both updrafts and downdrafts of air in the storm built in intensity along with the rain. These updrafts carried water vapor to higher, colder parts of the storm, allowing ice crystals to grow. However, ice accounted for only a small percentage of the storm's water, suggesting that Matmo's rainband was dominated by warm rain processes. Eventually, the number of raindrops dwindled as the storm dissipated.

The raindrop distributions that the authors observed in Typhoon Matmo were notably different from those of other storms, including seemingly similar typhoons in Taiwan: Matmo had a higher than usual concentration of smaller raindrops. Some degree of the difference can be accounted for by the environment, but further study will be required to fully probe the microphysical processes involved. A diverse set of data about tropical cyclones will help researchers build and validate numerical models of storms so that they can predict precipitation more precisely and mitigate damage. (*Journal of Geophysical Research: Atmospheres*, doi:10.1002/2016JD025307, 2016) **—Leah Crane, Freelance Writer**

Smoke Signals in the Amazon

In the world's largest rain forest, fires have increased in recent decades. The great Amazon rain forest in South America is typically resistant to fire because of damp foliage and the humid environment. However, scientists are seeing a surge in burning in the Amazon region, increasing carbon emissions into the atmosphere and affecting water cycles downstream of the Amazon River.

Researchers estimate that about 15% of the Amazon was deforested between 1976 and 2010. In that time, humans converted tropical forests and savannas to agricultural lands, sometimes using the slash-and-burn method, which creates an environment favorable to fires.

In a new study, *van Marle et al.* looked into the recent history of burning in the region from 1973 to 2014. Calculating the emissions from fires in the Amazon during that time and how much was connected to deforestation could help researchers better understand the impact of deforestation on the world's largest tropical rain forest.

The researchers used human-observed data gathered by World Meteorological Organization weather stations positioned throughout the Amazon. These observations included daily records of visibility around the weather station, using landmarks to measure how clear the day was or whether smoke impeded the view. The advantage of this data source is that it has a longer record than the satellite observations currently used to monitor fires around the globe.

Visibility can be negatively affected by pollution and by weather conditions, such as rain or fog. Therefore, the scientists excluded rainy and foggy days from their data set and aggregated the observations from each weather station into a daily average, which made it easier to compare the data. From there the researchers created a monthly record across 41 years.

The visibility data were compared to satellite estimates of fire emissions, where total particulate matter was taken from the Global Fire Emissions Database and carbon monoxide was directly observed by the Measurement of Pollution in the Troposphere (MOPITT) satellite sensor. Both particulate matter and carbon monoxide are products of forest fires. Finally, they compared the results to the net forest loss in the region, which comes from satellite data.

Fire estimates in the Amazon indicate that before 1987, fire-driven deforestation was relatively low. That changed rapidly in the 1990s, when fire emissions increased overall but with substantial variability from year to year. Although the decrease in deforestation in the Brazilian Amazon is to some degree reflected in the data showing lower fire emissions more recently, drought years such as 2010 still show high fire emissions. After comparing their burning estimates to deforestation data sets, the scientists concluded that deforestation could explain 33% of the fire signals observed in the Amazon region.

The results of the study reveal that converting forest to agriculture began toward the end of the 1980s, then increased quickly through the next decade, causing more burning in the process. However, the authors are somewhat cautious in their conclusions, acknowledging that deforestation methods could have changed since the 1980s and thus that the link between deforestation and fire may have changed over time. They also acknowledge that the subjective nature of human observation data could cause variability in the data set.

The study remains a solid estimate of the number of forest fires caused by anthropogenic deforestation across several decades and will be useful to climate scientists tracking the amount of carbon being released into the atmosphere from this region. (*Global Biogeochemical Cycles*, doi:10.1002/2016GB005445, 2017) **—Alexandra Branscombe, Freelance Writer**

Guido van der Werf, Vrije Universiteit Amsterdam

A plume of smoke billows above a farm field. Repeated burning can convert a tropical forest to land suitable for agriculture within one dry season.

Probing the Source Properties of Deep Earthquakes

FEMA

According to a recent study, different mechanisms may control the onset of shallow versus deep earthquakes, such as the 57-kilometer-deep Nisqually event that caused more than $1 billion in property damage in Washington State in 2001.

About 50 kilometers below Earth's surface, earthquakes occur primarily along subducting slabs at convergent plate boundaries. Although previous studies have demonstrated that these seismic events often have source properties that differ from shallower earthquakes, the physical processes responsible for deep earthquakes are still poorly understood.

To elucidate the mechanisms that control faulting at depths below 50 kilometers, *Poli and Prieto* have cataloged and studied the source parameters and developed detailed energy budgets for 415 moderate and large (magnitude greater than 5.8) earthquakes that occurred over the past 16 years at or below intermediate depths, between 50 and 350 kilometers. The results indicate that deep earthquakes have larger fracture energies than shallow events and that their fracture energies increase with greater amounts of fault slip, a finding that suggests that the mechanism of rupture for deep earthquakes differs from what has been observed for shallow events. The team also observed an increase in radiation efficiency—the amount of work that is mechanically dissipated—with depth, which indicates that the rupture mechanism may likewise vary between intermediate and deep earthquakes.

So what could be responsible for this different mechanism of rupture? Given the large catalog, the researchers were also able to examine how rupture parameters differ within the same subduction zone. Their analysis shows that these properties can vary along the fault and that the observed differences are likely controlled by the shape and age of the subducting slab, as well as by the occurrence of volcanic regions.

Collectively, these results constitute the most complete summary of deep earthquake source properties to date. The authors note that the results should help constrain which mechanisms control the nucleation and propagation of deep seismic events. (*Journal of Geophysical Research: Solid Earth*, doi:10.1002/2016JB013521, 2016) **—Terri Cook, Freelance Writer**

Major Ocean Circulation Pattern at Risk from Greenland Ice Melt

The Atlantic Meridional Overturning Circulation (AMOC) is a massive, looped belt of water that connects the world's oceans, carrying warm waters north and cold waters south. The system not only transports heat and nutrients but also affects key weather patterns like the Indian and African monsoons.

Climate models suggest potentially devastating consequences if this system is weakened or lost, including more shifts in precipitation patterns, extreme weather, and changes to regional sea levels. Scientists believe that climate change has the potential to switch AMOC "on" and "off"; however, they aren't yet certain what conditions would flip that switch.

In its most recent report, the Intergovernmental Panel on Climate Change stated that although AMOC could weaken as a result of human-induced global warming, it is unlikely to collapse entirely in the 21st century. The report did not include factors such as the melting of the Greenland Ice Sheet, however, which has accelerated over the past several decades, or the basic uncertainty surrounding AMOC's stability. Now *Bakker et al.* have included those factors in eight state-of-the-art climate models, projecting what is likely to happen under two separate climate scenarios up to and beyond the 21st century.

In one scenario, anthropogenic carbon dioxide (CO_2) emissions peak around 2040, then decline. Under these conditions, AMOC does not collapse entirely but weakens by about 18% by roughly 2090–2100, the scientists report.

In the second, "business as usual," scenario, emissions continue to rise at their current rate throughout the 21st century. In their models, the researchers found that by 2100, the system will lose about 37% of its strength. By 2290–2300, AMOC will diminish by approximately 75% and will have a 44% chance of collapsing entirely, the scientists report.

Although the latter scenario may sound bleak, it suggests that aggressive action to reduce CO_2 emissions could have a profound impact, according to the authors. Indeed, the likelihood of full collapse stays significantly smaller if global warming is limited to less than 5 K, they say. (*Geophysical Research Letters*, doi:10.1002/2016GL070457, 2016) **—Emily Underwood, Freelance Writer**

NASA Goddard Space Flight Center

Melt from Greenland's ice sheet, which will eventually reach the ocean. If the ice sheet collapses entirely, flushing ocean circulation patterns with fresh water, climate around the world will drastically change. However, new research shows that controlling carbon dioxide emissions could stave off this future.

Clouds in Climate Models of a Simulated Water-Covered Earth

Earth's atmosphere is teeming with waves. As atmospheric waves propagate around the equator, clouds often form as humid air ascends. These clouds and convective systems drive tropical rainfall along the Intertropical Convergence Zone, a ring around the globe near the equator where the northern and southern trade winds meet.

However, the zone's clouds are difficult to simulate individually in general circulation models (GCMs).

Cloud processes are too small to capture within the models' grids, which discretize the equations of fluid mechanics. Instead, researchers have to parameterize cloud effects at the grid size. Various choices can be made for those parameterizations in GCMs, and researchers study how those choices may affect the organization of clouds on a larger scale. For example, different cloud parameterizations can change simulated cloud behavior within atmospheric waves, such as Convectively Coupled Equatorial Waves (CCEWs), and within planetary-scale waves like the Madden-Julian Oscillation (MJO)—an eastward moving system of clouds, rainfall, and winds that circles the globe every 30 to 60 days, playing a major role in climate at subseasonal timescales.

Here *Leroux et al.* compare short-term tropical variability simulated by six atmospheric GCMs (AGCMs) to find out how different cloud parameterizations affect model output.

The researchers ran the AGCMs, which were part of the Earth System Model Bias Reduction and Assessing Abrupt Climate Change project, on aquaplanets—entirely water-covered Earths. Those aquaplanet simulations were run both with and without a regional "warm pool" on the equator—this pool mimics regionally warmer conditions at the surface as in the equatorial Indo-Pacific region.

Such idealized aquaplanet experiments allow researchers to eliminate the effects of the land-sea interface and mountains on the MJO, and thus to tease out the effects of model design and parameterization on model output. The authors found substantial differences in the simulated MJOs and CCEWs across the six models.

Previous research has suggested that westerly winds buoyed by warm pools might be necessary to drive the eastward movement of the MJO. Here, however, the authors found that only half the models produced low-level westerlies; in some models, very weak westerly winds led to a strong MJO, while in others, strong westerly winds were present but the MJO failed to materialize.

In addition, in about half the models, the warm pool was sufficient to induce MJO-like variability, but in the other half, it was not. This variability across models indicates that the importance of westerly winds and warm pools varies by model, and thus the presence or absence of both in a simulation does not predict that simulation's ability to accurately capture intraseasonal variability.

The model-specific differences arise from the parameterizations of subgrid processes like cloud dynamics, according to the authors. Future aquaplanet experiments across multiple model types could help researchers improve or design new parameterizations of such processes at a relatively low computational cost. (*Journal of Advances in Modeling Earth Systems*, doi:10.1002/2016MS000683, 2016) **—Kate Wheeling, Freelance Writer**

Boulders Limit Transport of Sand and Gravel in Steep Rivers

As streams and rivers flow, they carry sediments of various sizes, from fine sand to large boulders. Knowing the quantity of such transported sediments is vital for river engineering and natural hazard assessment. For example, in the case of flooding, knowing how much sediment a river can carry can help prevent disasters.

In a new study, *Schneider et al.* studied sediment transport at steep and gentle channel slopes in a glacier-fed Swiss mountain stream called Riedbach. Near the glacier source, the Riedbach has a comparatively gentle slope of 3%–6%. Over a 1-kilometer stretch, the Riedbach channel becomes very steep, with a slope of 30%–40%. Because it is driven by glacial melt, the stream fluctuates daily and seasonally, with its peak flow occurring during late afternoons in the summer.

The scientists used two methods to measure sediment transport rates in the 1-kilometer study stretch. In the low-gradient part of the Riedbach, they installed bed load traps, long, trailing nets with aluminum frame openings that collect gravel and cobbles as they roll along the streambed. The trapped sediment was emptied and weighed every hour.

Downstream of the steep reach, the scientists set up a Swiss plate geophone system, consisting of metal plates with vibration sensors lining the streambed. As gravel and cobbles hit these plates, they produce vibrations that are picked up by the sensors. The signals from the sensors were tallied each minute to measure the volume of sediment carried by the stream.

Although the Riedbach streambed gradient increases tenfold over the 1-kilometer stretch, the scientists found that the flow velocity and sediment transport rate were nearly the same in the steep reach and the gentle one. The flow velocity in the steep reach is limited by the drag of the flow against large boulders lining the bed of the channel. The increased flow resistance in the steep channel reduces the flow energy that is available to transport sediment.

The authors used the sediment transport observations to validate flow velocity and sediment transport equations that were created for low-gradient and moderately steep streams. They found that these equations could accurately predict flow velocities and sediment transport rates at very steep slopes if the additional drag from boulders was taken into account.

These equations work best during high flows, which are especially relevant for forecasting flood hazards. The results may help environmental researchers predict sediment transport during floods in mountain regions. (*Water Resources Research*, doi:10.1002/2016WR019308, 2016) **—Alexandra Branscombe, Freelance Writer**

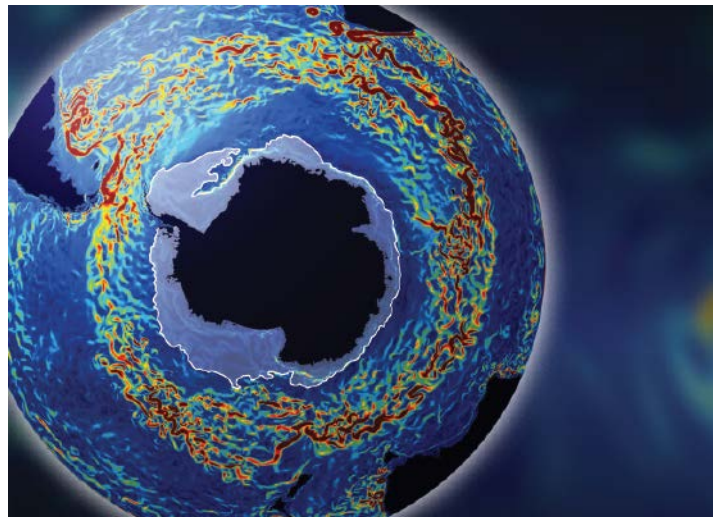
Notorious Ocean Current Is Far Stronger Than Previously Thought

Notorious among sailors for its strength and the rough seas it creates, the Antarctic Circumpolar Current (ACC) is the largest wind-driven current on Earth and the only ocean current to travel all the way around the planet. Now researchers have found that the current transports 30% more water than previously thought. The revised estimate is an important update for scientists studying how the world's oceans will respond to a warming climate.

The ACC transports massive amounts of water between the Atlantic, Indian, and Pacific oceans in an eastward loop. Just how much water has long been uncertain, however, because of the difficulty and expense of accurately measuring its flow.

For the new study, *Donohue et al.* installed gauges along the bottom of Drake Passage, spanning an 800-kilometer distance between Cape Horn and the South Shetland Islands of Antarctica. Housed in glass spheres and spaced between 30 and 60 kilometers apart along a line near the seafloor, the gauges included pressure sensors, floating current meters attached by 50-meter tethers, and instruments that measure acoustic travel time from the seafloor to the sea surface.

The classic estimate used for the ACC's transport is 134 sverdrups (Sv). One sverdrup is equivalent to 1 million cubic meters per second. Using 4 years of data collected from 2007 to 2011, the researchers found that the transport rate, around 173.3 Sv, was 30% higher than historical estimates. Although it's possible that stronger winds in the Southern Ocean over the past few decades may have caused the increase, satellite-based studies showing that transport has remained fairly steady during this time suggest that improved measurement tools, not increased wind, are responsible for the discrepancy. (*Geophysical Research Letters*, doi:10.1002/2016GL070319, 2016) **—Emily Underwood, Freelance Writer**



M. Mazloff, MIT; Source: San Diego Supercomputer Center, UC San Diego

An ocean circulation model shows the Antarctic Circumpolar Current swirling around Antarctica, with slow moving water in blue and warmer colors indicating faster speeds (red represents speeds above 1 mile per hour). But how much water is really flowing through the current? Recent fieldwork provides unexpected results.

Tracking Trends in U.S. Flood Risk

For 16 consecutive months in 2015 and 2016, Earth's climate repeatedly broke global temperature records, in keeping with global warming trends observed over the past century and counting. During that period, there were major floods across the United States, including events in Missouri, Texas, Oklahoma, West Virginia, Maryland, and Louisiana.

Warmer temperatures are associated with more frequent extreme precipitation events, and they increase the atmosphere's water-holding capacity, suggesting that flooding across the globe will become more frequent in coming decades. Such an increase would have costly consequences for agriculture, water resources management, ecology, insurance, and transportation and navigation industries, as well as for civilians living in flood-affected areas. In light of this, hydrologists and atmospheric scientists are working to develop a more nuanced understanding of projected flooding changes to accurately communicate risks to the public.

Slater and Villarini have carried out one of the first major investigations of regional changes in flood risk across the United States from 1985 to 2015. Using data from U.S. Geological Survey records, the researchers looked at 2042 catchments to determine the number of flood events that ranked above the National Weather Service's four flood categories: action (the stage first reached, indicating that some level of action must be taken to mitigate effects), minor (minimal public threat but some road inundation), moderate (some inundation of roads and structures, possibly requiring scattered evacuations), and major (extensive inundation of structures, requiring significant evacuations). Tracking these categories, which are used to monitor and forecast flood risk, helped them to understand how a region's flood risk had changed over time and how it might continue to change.

The researchers found that flood risk changes varied greatly from region to region, depending on a variety of factors, primarily overall wetness and potential water storage. For example, in southeastern Louisiana, they found that the number of days experiencing flooding has been gradually increasing (from "action" to "moderate" and beyond), whereas South Carolina's flood risk has been decreasing.

The researchers hope that their findings could be used to improve the communication of changing flood patterns to a wider audience, including industry leaders, policy makers, and the public. In the past, flood risk trends have typically been discussed in terms of the amount and frequency of flowing water. But this study introduces a new vocabulary for discussing flood risk trends, one that focuses on the localized threat to people and property. (*Geophysical Research Letters*, doi:10.1002/2016GL071199, 2016) **—Sarah Witman, Freelance Writer**

ATMOSPHERIC SCIENCES

Meteosat Third Generation (MTG) Programme Scientist, Europe's Meteorological Satellite Agency (EUMETSAT)

Europe's Meteorological Satellite Agency (EUMETSAT) is looking for an established scientist with a background in atmospheric remote sensing, radiative transfer, and physics to join the Meteosat Third Generation (MTG) Programme team.

The innovative MTG programme ensures continuity of the vital service from geostationary orbit and for the first time adds observations from infrared and ultraviolet/visible sounding instruments.

The new programme calls for a flexible and experienced scientist, willing to provide scientific leadership and support to the EUMETSAT MTG programme. Also, the successful candidate will lead a dedicated team of scientists and be required to coordinate scientific support to the development of the MTG system. You will also represent EUMETSAT at international events and liaise with the scientific community as required.

You should ideally have skills/experience in each of the following areas:

• Extensive background in remote sensing of meteorological products, atmospheric radiative transfer and physics;

• Proven experience of management of interactions between engineers and scientists involved in the development of software-intensive systems driven by user requirements, performance objectives and cost and schedule constraints

• Proven experience of leading science teams, developing people, managing performance and ensuring the long-term availability of business critical skills;

• At least 5 years experience in satellite data processing, retrieval of geophysical/meteorological products and assessment of data product quality;

• Demonstrable success in defining, implementing, and supervising work on operational satellite-based meteorological products;

• Experience liaising and working with external partner organisations and working groups;

• Resilient self-starter, with the ability to be flexible;

• Strong interpersonal and team working skills, and strength in written analysis, synthesis and presentation.

All applicants must be EUMETSAT member state nationals with a good working knowledge of the English language, both spoken and written.

BIOGEOSCIENCES

Research on the impacts of climate change on ocean circulation, biogeochemistry, and ecology, Princeton University

The AOS ocean biogeochemistry group seeks energetic and enthusiastic

postdoctoral researchers to participate in modeling and observational studies of climate impacts on ocean circulation and how these affect ocean biogeochemical cycles and ecology. This effort is part of a broad modeling and observational study of ocean circulation, the global carbon cycle, ocean ecology, and the impact of climate change on all of these. Areas of particular current interest include the Southern Ocean, and the detection and attribution of biogeochemical and ecological change in the ocean.

Individuals will join a vigorous interdisciplinary research group under the direction of Prof. Jorge Sarmiento and will be able to take advantage of a wide range of related research at Princeton University and NOAA/GFDL, as well as external collaborators at the member institutions of the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project sponsored by NSF Polar Programs. Available resources include climate and earth system models and major compilations of high quality global biogeochemical data sets, as well as the opportunity to participate in the SOCCOM initiative to dramatically increase Southern Ocean observations using autonomous biogeochemical-Argo floats.

Candidates must have received a Ph.D. in the earth sciences, applied math, or the physical, biological, or chemical sciences within three years of the starting date for the appointment. Training in oceanic sciences is strongly preferred, and strong modeling, quantitative, and/or statistical skills are a must. Postdoctoral appointments are initially for one year with the renewal for subsequent years based on satisfactory performance and continued funding. A competitive salary is offered commensurate with experience and qualifications.

Applicants are asked to submit vitae, a statement of research experience and interests, and names of at least 3 references to https://www.princeton.edu/acad-positions/position/206. Review of applications will begin as soon as they are received, and continue until the position is filled. This position is subject to the University's background check policy.

Princeton University is an equal opportunity/affirmative action employer and all qualified applicants will receive consideration for employment without regard to age, race, color, religion, sex, sexual orientation, gender identity or expression, national origin, disability status, protected veteran status, or any other characteristic protected by law.

HYDROLOGY

Associate Professor, Ecohydrology, University of Arizona

The School of Natural Resources and the Environment (SNRE; http://snre.arizona.edu/) at the University of Arizona (UA) (http://www.arizona.edu/) seeks outstanding applicants for a tenure-eligible position in Ecohydrology at the rank of advanced Assistant or Associate Professor of Ecohydrology excited to join our growing interdisciplinary faculty and complement our existing research strengths. Successful applicants will be expected to continue their externally funded research program focused on interactions between the biosphere and the hydrological cycle, and to contribute to excellence in teaching and outreach within the School of Natural Resources and the Environment. We encourage applications from candidates with a strong physical science focus and research interests in one or more of the following areas: riparian systems, water supply and water quality, stream hydrology, applied geomorphology, ecophysiology, biometeorology, the soil-water-plant continuum, sustainability and conservation of water resources. This position offers the opportunity for applicants to engage in multiple exciting interdisciplinary initiatives including research made possible through the School's partnerships with the Critical Zone Observatory Network, the Santa Rita Experimental Range, the Walnut Gulch Experimental Watershed, the Landscape Evolution Observatory at Biosphere 2, the National Ecological Observatory Network (NEON).

Applicants can apply online at https://uacareers.com/postings/15729.

Review of applications will commence February 3, 2017 and continue until a suitable candidate is found. Start date is negotiable.

Direct questions about the position to the chair of the search committee: Professor David Moore, Chair of the Search Committee (davidjmoore@email.arizona.edu).

INTERDISCIPLINARY

Chief Executive Officer (CEO), National Ground Water Association (NGWA)

The National Ground Water Association (NGWA) seeks a collaborative, forward-thinking Chief Executive Officer to lead the organization in partnership with the Board of Directors. NGWA is a hybrid international trade association and scientific professional society working together to advance groundwater knowledge and the success of members through education and outreach; advocacy; cooperation and information exchange; and enhancement of professional practices. NGWA

Vice President for Academic Programs and Dean

The VP/Dean, head of WHOI's Academic Programs Office, is responsible for Institutional educational policy, programs, and budgets, oversees postdoctoral and undergraduate research programs and works with his/her counterpart at the Massachusetts Institute of Technology (MIT) to coordinate the graduate-level MIT-WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering. The VP/Dean works with the Development Office to solicit support for educational activities.

The VP/Dean is a member of Senior Administration, reporting directly to the President/Director and is an active contributor to all aspects of the Institution. Strong commitment to scholarship and education is essential, demonstrated by a distinguished record in research, teaching, academic leadership, and management. A Ph.D. or experience in a discipline related to ocean science is required.

WHOI is the largest private, non-profit oceanographic institution in the world. To learn more about this 12-month position, please contact the search committee chair, Dr. Claudia Cenedese, at 508-289-2696 or ccenedese@whoi.edu. To apply, please go to http://jobs.whoi.edu under 'Administrative Positions'. Review of applications will begin March 1, 2017.

Women and Minorities are strongly encouraged to apply. WHOI is sensitive to issues of confidentiality and dual career families. WHOI is an Affirmative Action/Equal Opportunity Employer.

Ocean Prediction Postdoctoral Positions Naval Research Laboratory, Stennis Space Center, MS

U.S. NAVAL RESEARCH LABORATORY

The Naval Research Laboratory is seeking postdoctoral researchers to push forward the frontiers of ocean forecasting. The work covers a wide scope of physics including surface waves, thermohaline circulation, nearshore circulation, and ocean/atmosphere coupling from global to nearshore scales. This challenging work includes processing and analysis of satellite and in water observations, construction of numerical model systems on high performance computing systems and assimilation for predicting the ocean environment. For a quick overview of some of the research work within the NRL oceanography division at Stennis Space Center, visit the web site:
https://www7320.nrlssc.navy.mil/pubs.php

Applicants must be a US citizen or permanent resident at time of application. Applications will be accepted until positions are filled. Please e-mail a resume and description of research interests:

Gregg Jacobs: gregg.jacobs@nrlssc.navy.mil

also operates a charitable foundation, the NGWA Foundation, focused on education, research and charitable activities related to broader public understanding of groundwater.

The CEO manages a staff of 29 and a budget of $5.5 Million, serves roughly 10,500 members and provides strategic vision and leadership to steward the future of the association and advance NGWA's goals.

The CEO has a strong external presence and needs a natural ability to collaborate, harness the collective voice of the groundwater industry, and cultivate relationships globally. Regular travel and public speaking engagements are an important part of this position.

The ideal candidate will be a seasoned executive leader with a strong track record of successfully leading and developing teams, working with an engaged Board, diversifying revenue streams, and leading strategic planning.

To Apply:

NGWA has retained Nancy Rummel of Nancy Rummel & Associates to assist in this search. Candidates should submit a letter of interest with salary requirement and resume to: Nancy@nancyrummel.com . Deadline for application is March 31, 2017.

Located in Westerville, Ohio. To learn more about NGWA, visit: www.ngwa.org

Faculty Position in Water Resources, Stanford University

Stanford University, in conjunction with its Woods Institute for the Environment, seeks nominations and applications for a faculty appointment in the area of water resources. We are interested in candidates who take a systems-based approach to water resources, regardless of their disciplinary background or training. Possible areas of expertise include but are not limited to hydrology and ecohydrology; water management and systems; governance and institutions; river geomorphology; risk management; multi-objective decision making; political science; big data and computation; and geochemical, geophysical, and remote sensing. Issue areas of interest include the design of effective water institutions and systems; climate change and adaptation (including management of extreme events); river and watershed restoration; dam removal & design; coastal river systems; and the nexus among food, water, and energy.

This is a tenure-line appointment and will be joint between the Woods Institute and a department appropriate to the candidate in any one of Stanford's seven schools. The Woods Institute (http://woods.stanford.edu) is the interdisciplinary hub for environmental research, teaching, and problem solving at Stanford. The level of the appointment is open, and candidates at all levels of experience are encouraged to apply.

We seek a motivated, broad-thinking scholar to pursue a vigorous research program and leadership role in Stanford's growing interdisciplinary water community. The successful candidate will be expected to be an active participant in the Water in the West program (http://waterinthewest.stanford.edu), as well as Stanford's other campus-wide water programs. A joint program of the Woods Institute and the Bill Lane Center for the American West (http://west.stanford.edu), Water in the West harnesses Stanford's resources toward solving the West's growing water scarcity problems. In addition to research, the successful candidate will teach classes and mentor students at both the graduate and undergraduate levels. We are particularly interested in candidates with an interest in interdisciplinary collaboration and working at the intersection of academic research and public policy.

Applicants are asked to provide a cover letter describing research and teaching experience as well as future plans in these areas as well as curriculum vitae. The committee will request letters of recommendation for finalists. Please submit the requested materials in a .pdf format via online at Academic Jobs Online, Job #8833. The job can be found at https://academicjobsonline.org/ajo/jobs/8833.

Review of applications will begin immediately and will continue until the position is filled.

Stanford University is an equal opportunity employer and is committed to increasing the diversity of its faculty. It welcomes nominations of and applications from women and minority groups, as well as others who would bring additional dimensions to the university's research, teaching, and clinical missions.

Postdoctoral Fellowship in Lunar and Asteroid Exploration Science, Universities Space Research Association

USRA is an independent, nonprofit research corporation where the combined efforts of in-house talent and university-based expertise merge to advance space science and technology. USRA works across disciplines including biomedicine, planetary science,

青岛海洋科学与技术国家实验室
Qingdao National Laboratory for Marine Science and Technology

Global Talent Search

For more information, please refer to: www.qnlm.ac/en/index

1. Positions and job descriptions

(1) Principal investigators (PI) for the six major research areas

Building a high-quality research team to conduct frontier research and train talented researchers; set strategic development plans; manage major projects throughout the whole lifecycle.

(2) One director for each joint lab *(High-End Ocean Equipment, Ocean Observing and Detecting, Blue Fishery, Smart Ocean, Intelligent Marine Computing and Big Data, Ocean Oil-Gas Resource Prospecting, New Marine Materials, Sustainable Ocean Energy, Deep-Sea Extreme Environment)*

Make development plans and propose strategic research directions; organize and lead state-level or international major scientific projects; build high-level research teams.

(3) One chief engineer for each public research platform *(R&D Center for Marine Instruments and Apparatuses, Center for Marine Isotopes and Geochronology)*

Lead the planning, construction and operation of public research platforms; provide technical support for the operation and maintenance of equipment; lead equipment testing and R&D for major state project; build a high-level technical support team.

2. Qualifications

(1) For PIs and directors

Having held professorship (or principal investigator) or other senior positions; World-recognized academic achievements in relevant areas; Outstanding leadership skills; Full-time affiliation or at least six months for PIs in QNLM each year.

(2) For chief engineers

Relevant experience of equipment maintenance and R&D at world-famous institutions, along with rich management experience for major research projects; Excellent R&D track; Full-time affiliation or at least six months each year in QNLM during the transition period (up to two years for overseas applicants).

3. Remunerations

(1) For PIs

Allowance: RMB 1-1.2 million per year; Research subsidy: RMB 3-5 million; RMB 5 million home purchase subsidies on a contract of six years or longer with QNLM; or a rental-free apartment of around 180m^2 on a less-than-six year contract with QNLM.

(2) For directors and chief engineers

Open to face-to-face negotiations; refer to relevant QNLM Aoshan Talent policies.

4. How to apply

Applicants need to submit a CV, previous research achievements (a list of up to ten most significant publications or patents), a research plan and work objectives and three references, all in PDF; The complete submission, referenced as "Application for QNLM Aoshan Recruitment Program", should be emailed to: jwzheng@qnlm.ac.

5. Deadline

Review of applications will begin immediately and continue until the positions are filled.

6. Contact information

Tel: +86-532-5871 9798

Fax: +86-532-5871 9758

E-mail: jwzheng@qnlm.ac

astrophysics, and engineering and integrates those competencies into applications ranging from fundamental research to facility management and operations. USRA engages the creativity and authoritative expertise of the research community to develop and deliver sophisticated, forward-looking solutions to Federal agencies and other customers – on schedule and within budget.

The Universities Space Research Association's Lunar and Planetary Institute (LPI), invites applications for postdoctoral fellowships in lunar and asteroid exploration science for full-time exempt positions in the Houston, Texas area. The successful candidates will join Dr. David A. Kring and over two dozen other scientists in the Center for Lunar Science and Exploration, which is one of nine national centers of excellence supported by NASA's Solar System Exploration Research Virtual Institute. The main goals of the Center's activities are to address NASA's highest lunar and asteroid exploration science objectives, including activities in preparation of robotic and crewed landings.

Applications from those with recent Ph.D.s in the fields of petrology and geochemistry are encouraged to apply. The successful candidate will work at LPI and use the analytical facilities at the adjacent NASA Johnson Space Center (JSC) and nearby University of Houston. Previous experience with lunar samples, chondritic meteorites, and/or impact lithologies will be advantageous. Expertise with U-Pb geochronology using LA-ICP-MS techniques will also be advantageous. Applications from those with experience using analytical, hydrocode, or remote sensing techniques to study impact and volcanic processing of the lunar environment or collisional consequences for asteroid surfaces that may be visited by human-assisted robotic assets or astronauts are also encouraged to apply for a possible second position.

If there are any questions about the science and exploration involved in the position, please contact Dr. David A. Kring (kring@lpi.usra.edu). Interested applicants should apply to the posting at https://usracareers.silkroad.com/ and must submit a curriculum vita with list of publications, a two to three page statement of research interests, and a list of three references. There is no firm application deadline, although a review of applications will begin March 1, 2017. Additional details of the Center's activities at the LPI and JSC are available at http://www.lpi.usra.edu/exploration/.

USRA is an Equal Opportunity Employer Minorities/Females/Protected Veterans/Disabled/Sexual Orientation/Gender Identity.

Professor and Chair Position, Iowa State University

The Department of Geological and Atmospheric Sciences at Iowa State University invites applications for the position of chairperson, at the rank of tenured full professor. Primary responsibilities of the department chair are to provide visionary leadership for programs in geology and meteorology; to encourage excellence and innovation in research, teaching, and service; to advance professional development of faculty, staff, and students' to promote productive relationships with all external constituents including, alumni, industry and government agencies; to foster productive relationships with a variety of entities across the university community; to promote diversity and inclusion among all students, faculty, and staff; and to facilitate faculty efforts to attract extramural grant and contract funding. The chairperson also carries the title, "Smith Family Foundation Chair of Geology" and in that role uses the earnings that accrue annually from the Smith Foundation and Morehouse endowments to advance the teaching and research missions of the Geology Program.

Candidates must hold a Ph.D. in geosciences, atmospheric sciences, or a closely related discipline at the time of appointment and have credentials appropriate for the rank of professor, including scholarly contributions to the field that have earned national recognition.

The successful applicant will have a demonstrated record of effective leadership or administrative experience in higher education or the research community. Applicants will also have a demonstrated record of accomplishment in all areas of responsibility (research, teaching, service) in prior academic appointments, with evidence of commitment to supporting the teaching and research missions of a major research university. Evidence of commitment to creating a climate of diversity and inclusion for students, faculty and staff is also required.

All applications must be submitted electronically at www.iastatejobs.com (search vacancy ID# 700001). Please be prepared to enter or attach a letter of application including concise teaching and research statements, curriculum vitae, and the names, street and e-mail addresses, and phone numbers of at least three references.

The position will remain open until filled. Full consideration will be given to those applications received by February 15, 2017.

Iowa State University is an Equal Opportunity/Affirmative Action employer. All qualified applicants will receive consideration for employment without regard to race, color, age, religion, sex, sexual orientation, gender identity, genetic information, national origin, marital status, disability, or protected veteran status and will not be discriminated against. Inquiries can be directed to the Office of Equal Opportunity, 3410 Beardshear Hall, 515 Mor-

Section Head, Integrated Activities Section
Division of Earth Sciences
National Science Foundation (NSF)
Arlington VA

NSF's Directorate for Geosciences (GEO) seeks candidates for the position of Section Head for the Integrated Activities Section in the Division of Earth Sciences (EAR). The Section Head serves as a member of the Division leadership team and as a spokesperson for Earth Sciences research. The Section Head is responsible to the EAR Division Director for overall planning, management, and commitment of budgeted funds for the Section, which includes programs in instrumentation and facilities, education and human resources, and cross-division research programs including integrated Earth systems, EarthScope, and critical zone observatories.

Appointment to this Senior Executive Service position will be on a career basis, with a salary range of $160,300-$177,800. The job opportunity announcement (EAR-2017-0002) with position requirements and application procedures may be view at: https://www.usajobs.gov/GetJob/ViewDetails/462369900?org=NSF.

NSF is an equal opportunity employer committed to employing a highly qualified staff reflecting the diversity of our nation.

RUTGERS
Institute of Earth, Ocean, and Atmospheric Sciences

EOAS
EDUCATION. RESEARCH. DISCOVERIES.

Postdoctoral Fellowships in Earth, Ocean, and Atmospheric Sciences

The Institute of Earth, Ocean, and Atmospheric Sciences at Rutgers University (**eoas.rutgers.edu**) invites applications for two Postdoctoral Fellowships to be awarded in Fall 2017. Our strong research programs include focuses on global climate change, ocean modeling and observations, paleoceanography and Earth history, planetary science, geobiology, marine ecology, molecular ecology, and environmental biophysics. We seek proposals to conduct innovative transdisciplinary research in these subject areas. Applicants should contact one or more members of the EOAS faculty and develop a three-page research proposal. The application package should include a cover letter, Curriculum Vitae, and a research proposal. Please send to **keng@marine.rutgers.edu** under the heading EOAS Postdoctoral Appointments. Applications will be reviewed beginning in late-February and will continue until the positions are filled.

Rutgers is an Equal Opportunity/Affirmative Action employer.

rill Road, 515 294-7612, e-mail eooffice@iastate.edu.

SPACE PHYSICS

Ionospheric Research Scientist, U.S. Naval Research Laboratory, Space Science Division

The Geospace Science and Technology Branch of the Space Science Division at the Naval Research Laboratory invites applications for a permanent Research Scientist position. We conduct research to observe, understand, model, and forecast the ionosphere, in order to improve capabilities for the Navy/Marine Corps, other services, and agencies. For more information see our web site, https://www.nrl.navy.mil/ssd. Experience in one or more of the following research areas is required: physics-based modeling, data assimilative modeling, ionospheric sensor data analysis, radio propagation modeling, or the effects of the ionosphere on radio-based systems. A PhD, or equivalent, and postdoctoral experience are highly desirable. Salary will be determined based on background, experience, and market consideration. Candidates should send their application electronically to geospace@nrl.navy.mil. The application consists of a curriculum vitae, including a list of publications and a description of research interests. Candidates should also be prepared to arrange for three letters of reference to be forwarded electronically upon request. US citizenship is required and candidates must be able to obtain and maintain a DoD Security Clearance. NRL is an Equal Opportunity Employer.

Tenure-track Faculty, Clemson University

We seek candidates with a strong proven record in experimental work with emphasis on the Earth's upper atmosphere and ionosphere. The atmospheric and space physics group within the department currently has strong research programs in rocket and ground-based observations, with technical support provided by the department's instrument shop. Our research program also includes work in satellite diagnostics, modeling and big data, and we seek someone that can complement and enhance the research activities of the department. The successful candidate will be expected to establish a vigorous externally funded research program, exhibit a record of substantive research, and a commitment to excellence in teaching at both the undergraduate and graduate level. Required qualifications include a PhD in Physics, or closely related field. Applications should be submitted via Interfolio (apply.interfolio.com/39806) and include a curriculum vitae, publication list, statements of research interests and accomplishments, a research plan, a statement of teaching philosophy, and the names of at least three references. Applicant evaluations will begin on February 15, 2017 and continue until the position is filled. Information about our research and educational programs can be found at physics.clemson.edu. For further information, please contact cuphysicsjob@clemson.edu. Clemson University is an AA/EEO employer and does not discriminate against any person or group on the basis of age, color, disability, gender, pregnancy, national origin, race, religion, sexual orientation, veteran status or genetic information. Clemson University is building a culturally diverse faculty and staff committed to working in a multicultural environment and encourages applications from minorities and women.

W1 Junior Professorship Arctic Climate Changes (with tenure track leading to W2), University of Leipzig, Germany

The Faculty of Physics and Geosciences seeks to fill a Junior Professorship in Arctic climate changes, in particular of interactions and feedback mechanisms of ocean, sea ice, and land surfaces with the atmosphere. The application, combination, and advancement of respective observational and modeling tools is a major strength. A close collaboration with resident institutes in the area of remote sensing of land surface processes is anticipated. An active contribution to the Transregional Collaborative Research Center on "Arctic Amplification" is expected (http://www.ac3-tr.de/).

Applicants should submit a cover letter, CV, teaching and research statements, and a certified copy of the highest academic degree, before 31 March 2017 to: dekan@physik.uni-leipzig.de.

Postcards from the Field

Dear Everyone:

We are out tending the Muskegon Lake Observatory buoy (MLO). Muskegon Lake is an urbanized Great Lakes estuary connecting Michigan's second-largest watershed to Lake Michigan, the second-largest Laurentian Great Lake. MLO provides time series weather, water quality, and water circulation data from multiple depths and is in its sixth year of deployment. Over the years, MLO has been revealing stunning time-lapse details of underwater phenomena such as mixing, stratification, hypoxia, and cyanobacterial blooms in this dynamic coastal ecosystem. MLO data are freely available on the buoy website (www.gvsu.edu/buoy/).

—Bopi Biddanda, Anthony Weinke, and **Scott Kendall,** Annis Water Resources Institute, Grand Valley State University, Muskegon, Mich. (www.gvsu.edu/wri/)

View more postcards at
http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.

AGU FALL MEETING

New Orleans | 11–15 December 2017

Think Creative. Think Collaborative. Think Transdisciplinary.

Have an Idea or Topic to Present at the Fall Meeting?

Submit a Session Proposal

Deadline:
19 April, 11:59 P.M. EDT

You must have a current 2017 AGU membership to propose a session.

fallmeeting.agu.org

GeoHealth

AN OPEN ACCESS AGU JOURNAL

GeoHealth will foster the intersection of Earth science disciplines (Earth processes, climate change, atmospheric and ocean sciences, hydrology, among others), with those of the health sciences, defined broadly (environmental and ecosystem health and services, human and agricultural health, geomedicine, and the impact of natural hazards).

Now Accepting Applications for Two Editors in Chief of *GeoHealth*

AGU is launching *GeoHealth* under Founding Editor Rita R. Colwell. We are seeking applications for two dynamic, well-organized scientists with high editorial standards and strong leadership skills to serve 4-year terms as the editors in chief (EICs) to lead this exciting journal starting in 2017 and beyond. One editor's main area of focus will be on the geosciences, while the other editor's main area of focus will be on health.

This is an important opportunity to help shape and lead this increasingly important, cross-cutting discipline. The EICs will be the principal architects of the scientific content of the journal. They are active scientists, well-known and well-regarded in their respective discipline. The EICs must be active in soliciting the best science from the best scientists to be published in the journal. Working with the other editors and AGU staff, EICs are the arbiter of the content of the journal. Among other functions, EICs will be responsible for:

- **Acting as an ambassador to the author/editor/reviewer/scientist community.**
- **Setting the strategy for the journal.**
- **Leading the editor selection process.**
- **Assigning and balancing review work load.**
- **Making decisions related to scientific ethics.**
- **Reviewing and contributing to periodic monitoring reports.**
- **Conducting and attending meetings.**

If you would like to be considered for one of the Editor in Chief positions of *GeoHealth,* send your curriculum vitae with a letter of interest via email to pubmatters@agu.org. If you would like to nominate a highly qualified colleague, send a letter of recommendation to the same email address. **Please make sure that you specify *GeoHealth* in the subject line of the email.**

geohealth.agu.org

AGU PUBLICATIONS